THE SOUTH AFRICAN JOURNAL OF SCIENCE

VOLUME XXXIV

BEING THE

REPORT

OF THE

THIRTY-FIFTH ANNUAL MEETING

OF THE

SOUTH AFRICAN ASSOCIATION

FOR THE

ADVANCEMENT OF SCIENCE

WINDHOEK

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1937

SOUTH AFRICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

Form of Application for Membership.

To the Assistant General Secretary,

South African Association
for the Advancement of Science,
P.O. Box 6894, Johannesburg.

I desire to become *................................ member of the South African Association for the Advancement of Science, and for this purpose I enclose a Cheque for £.............................†

1. Name in full ....

2. Academic Degrees or Diplomas, Fellowships of Learned Societies, etc., held (if any) ....

3. Profession or Occupation ......

4. Full Postal Address ....

5. Signature ....

Date

* Please state whether "Ordinary Member," "Life Member," or "Associate Member." Subscriptions are as follows: Life Members, £15; after ten consecutive years as an Ordinary Member, £7 10s. Ordinary Members, £1 10s. per annum. Associate Members, £1, for period of the Annual Session only. Student Members (not exceeding 23 years), 10s. 6d. for period of Annual Session only. (Associate and Student Members are not entitled to receive the JOURNAL of the Association.)‡

Candidates resident in the Witwatersrand (Randfontein to Springs) should add the sum of £1 1s. for membership of the Associated Scientific and Technical Societies of South Africa.

† Cheques, etc., should be crossed and made payable to the Assistant General Secretary, South African Association for the Advancement of Science, and 6d. should be added to the country cheques to cover exchange.

‡ Student members will be supplied with the JOURNAL at the reduced price of 10s.; application for this privilege must be countersigned by the Head of the University Department in which the student is working.

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(1937, WINDHOEK.)

Vol. XXXIV. JULY, 1937. Vol XXXIV.

EDITORIAL NOTE.

The present editor is again stepping into the breach. This time, at the request of the Council of the Association, he is deputising for Professor John Phillips, who is now on leave in the United States of America.

The volume which is now laid before the reader, though considerably less bulky than its immediate predecessor, offered a number of difficulties which the printers materially assisted the editor to overcome. To them, and to Mrs. H. M. McKay, who rendered valuable service, and to the authors who facilitated his task, his sincere thanks are due.

L. F. Maingard

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CONSTITUTION and BY-LAWS

OF THE

SOUTH AFRICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

(As amended at the Thirty-second Annual General Meeting, held at Paarl, 1935.)

CONSTITUTION.

OBJECTS.

1. The objects of the Association are :—To promote the intercourse of societies and individuals interested in Science in different parts of South Africa; to obtain a more general attention to the objects of pure and applied Science, and the removal of any disadvantages of a public kind which may impede its progress; to give a stronger impulse and a more systematic direction to scientific enquiry and research.

MEMBERSHIP.

2. The Association shall consist of (a) Life Members, (b) Honorary Life Members (limited to ten in number), (c) Ordinary Members (groups (a), (b), (c) shall be included under the term " Members "), (d) Institutional Members, (e) Temporary Members, elected for a session, hereinafter called " Associates," (f) Student Members, persons not exceeding 23 years of age, being students of universities or of any educational institutions recognised by the Council.

3. All persons interested in the objects of the Association are eligible for Membership. All persons desirous of becoming Members shall be proposed and seconded by Members of the Association.

4. Institutions, Societies, Government Departments and Public Bodies are eligible as " Institutional Members."

5. Members, Institutional Members and Associates shall be elected directly by the Council, but Associates may also be elected by Local Committees. Members may also be elected by a majority of the Members of Council resident in that centre at which the next ensuing Session is to be held.

6. The Council shall have the power, by a two-thirds vote, to remove the name of a Member of any class, whose Membership is no longer desirable in the interest of the Association.

7. The Council shall have the power to strike off the roll of the Association the names of Members whose subscription are in arrear for two years, due and proper notification having been previously given.

PRIVILEGES OF MEMBERS AND ASSOCIATES.

8. Life Members shall be eligible for all offices of the Association, and shall receive all ordinary publications issued by the Association.

9. Ordinary Members shall be eligible for all offices of the Association, and shall receive all ordinary publications issued by the Association during the year of their admission, and during the years in which they continue to pay their Annual Subscription.

10. Institutional Members shall receive all ordinary publications of the Association on the same conditions as Ordinary Members, and each Institutional Member shall be entitled to send one representative to the Annual Session of the Association.

11. Associates are eligible to serve on the Reception Committee, but are not eligible to hold any other office, and they, as well as Student Members, are not entitled to receive gratuitously the publications of the Association.

12. No Member or Associate or Student Member shall be entitled to the privileges of the Association until his or her dues have been paid.

SUBSCRIPTIONS.

13. Every Life Member shall pay, on admission as such, the sum of Fifteen Pounds.

14. Ordinary and Institutional Members shall pay, on election, an Annual Subscription of One Pound Ten Shillings. Subsequent Annual Subscriptions shall be payable on the first day of July in each year.

15. An Ordinary Member may at any time become a Life Member by one payment of Fifteen Pounds in lieu of future Annual Subscriptions. An Ordinary Member may, after ten years, provided that his subscriptions have been paid regularly without intermission, become a Life Member by one payment of Seven Pounds Ten Shillings in lieu of future Annual Subscriptions.

16. The Subscription for Associates for a Session shall be One Pound, and for Student Members shall be Ten Shillings and Sixpence.

RESIGNATIONS.

17. Members resigning on or after the 31st August of any year shall be liable for the subscription for that year.

MEETINGS.

18. The Association shall meet in Session annually. The place of meeting shall be appointed by the Council as far in advance as possible, and the arrangements for it shall be entrusted to the Local Committee, in conjunction with the Council.

COUNCIL.

19. The Management of the affairs of the Association shall be entrusted to a Council.

20. The Council shall consist of the President, four Vice-Presidents, two General Secretaries, General Treasurer, the Editor of the Publications of the Association, and the Librarian, together with one Member of Council to every fifteen Members of the Association. The immediate Past President shall be, *ipso facto*, a member of Council.

21. The President, Vice-Presidents, General Secretaries, General Treasurer, the Editor of the Publications of the Association and the Librarian shall be nominated at a meeting of Council not later than two months previous to the Annual Session, and shall be elected at the Annual General Meeting.

22. Ordinary Members of Council to represent centres having more than fifteen Members shall, not later than one month prior to the Annual Session of the Association, be elected by each such Centre, in the proportion of one representative for every fifteen Members. The Annual General Meeting shall elect other Ordinary Members of Council, in numbers so as to give, together with the Members of Council already elected by the Centres, in all, one Member of Council for every fifteen Members of the Association. In voting for members of Council, absent Members may record their votes in writing.

23. At meetings of Council five Members shall form a quorum, and all matters shall be decided by a majority, the Chairman to have a casting vote.

24. The Council shall have the power to co-opt Members, not exceeding five in number, from among the Members of the Association resident in that Centre at which the next Session is to be held, and also shall have power to co-opt as a Member of Council the Mayor of the town where the Session is to be held.

25. In the event of a vacancy occurring in the Council, or among the Officers of the Association, in the intervals between the Annual Sessions, or in the event of the Annual Meeting leaving vacancies, the Council shall have the power to fill such vacancies, and to appoint Honorary Corresponding Members of Councils at such centres as the Council may deem desirable.

26. During any Session of the Association the Council shall meet at least twice, and the Council shall meet at least six times during the year, in addition to such meetings as may be necessary during the Annual Session of the Association.

27. The Council shall have power to appoint and dismiss such paid officers as may be necessary to carry on the work of the Association, on such terms as the Council may from time to time determine. The Assistant General Secretary shall act under the instructions of the General Secretaries. He shall also act on the directions which may be given him by the General Treasurer in that part of his duties which relate to the finance of the Association, and shall give assistance to the Editor and to the Librarian as required.

28. The Council shall have power to appoint Sub-Committees for such purposes and with such powers as the Council may determine.

29. The Council shall have power to make, amend or repeal By-Laws, which shall not be inconsistent with the terms of the Constitution, in order to facilitate the working of the Association.

HEADQUARTERS.

30. The Headquarters of the Association shall be in Johannesburg.

FINANCE.

31. The Financial Year shall end on the 31st May.

32. All sums received for Life Subscriptions and for Entrance Fees, if any, shall be invested in the names of at least three Trustees appointed by the Council. The Fund so formed shall be called the Endowment Fund, and only the interest arising therefrom shall be applied to the uses of the Association, except by resolution of a General Meeting; provided that any composition fee as a Life Member paid over to the Trustees of the Endowment Fund after the 30th day of May, 1914, may, upon the death of such Member, be repaid by the Trustees to the General Account of the Association, if the Council shall so decide.

33. All cheques shall be signed by the General Treasurer and a General Secretary, or by such other person or persons as may be authorised by the Council.

34. Whenever the balance in the hands of the Treasurer shall exceed the sum requisite for the probable or current expenses of the Association, the Council may invest the excess on fixed deposit with the bankers to the Association or in such securities as may from time to time be approved by the Council, or apply it to the increase of the Endowment Fund.

35. On the request of the majority of the Members of Council of any recognised Local Centre, the Council shall empower the local Members of Council in that Centre to expend sums not exceeding in the aggregate 10 per centum of the amount of Annual Subscriptions raised in that Centre.

36. The Local Committee of the Centre in which the next ensuing Session is to be held shall have the power to expend money collected, or otherwise obtained in that Centre, other than the subscriptions of Members. Such disbursements shall be audited, and the financial statement and the surplus funds forwarded to the General Treasurer within one month after the Annual Session.

37. The whole of the accounts of the Association, *i.e.*, the local as well as the general accounts, shall be audited annually by an auditor appointed by the Council, and the balance sheet shall be submitted to the Council at the first meeting thereafter, and be printed in the Annual Report of the Association.

TRUSTEES.

38. The Council shall have the power to appoint any person or persons to accept and hold in trust for the Association any money or property belonging to the Association or in which it is interested, or for any other purposes, and to execute and do all such deeds and things as may be requisite in relation to any such trust. The Council shall have the power from time to time to fill up any vacancy, provided always that the appointment of any Trustee or Trustees shall be subject to confirmation at the next Annual General Meeting. The Association, in Annual General Meeting, upon recommendation of the Council, due notice of three months having been given, may, if such course be deemed expedient, remove any Trustee or Trustees.

ALTERATIONS TO CONSTITUTION.

39. Any proposed alteration to the Constitution—

(a) Shall be intimated to the Council three months before the next Session of the Association.

(b) Shall be duly considered by the Council and communicated by circular to the Members of the Association for their consideration, and dealt with at the said Session of the Association.

(c) In voting on questions connected with alteration to the Constitution, absent Members may record their votes in writing.

40. During the interval between two Annual Sessions of the Association, any alterations proposed to be made in the rules shall be valid if agreed to by two-thirds of the Members of the Council. Such alteration of rules shall not be permanently incorporated in the Constitution until approved by the next Annual Meeting.

RULES FOR THE AWARD OF MEDALS.

41. THE SOUTH AFRICA MEDAL—

I.—CONSTITUTION OF COMMITTEE.

(a) The Council of the South African Association for the Advancement of Science shall, annually and within three months after the close of the Annual Session, elect a Committee to be called "the South Africa Medal Committee," on which, as far as possible, every Section of the Association and each Province of South Africa shall have fair representation.

(b) The Committee shall consist of twelve Members, of whom not less than four were Members of the previous Committee, and of whom not more than three shall represent any one Section of the Association.

The representation of the Provinces shall, in the first instance, be on the following basis :—

Transvaal	2
Cape	2
Natal	1
Orange Free State	1

A first ballot shall take place to secure this representation, thus electing six members to the Medal Committee. The result of this first ballot shall be communicated to all Members of Council, stating which of the Members so elected were Members of the previous Medal Committee, and which Sections are represented by them.

A second ballot shall then take place to secure the remaining six Members; and these shall be elected so as to secure amongst the twelve Members of the Committee *(a)* four Members from the Committee of the previous year, and *(b)* at least one representative from each Section. Each ballot paper must comply with these conditions or otherwise be declared void.

(c) The Chairman of the Committee shall be appointed annually by the Council from amongst its Members.

(d) Any casual vacancy in the Committee shall be filled by the Council.

II.—Duties.

(a) The duties of the Committee shall be to administer the Income of the Fund and to award the Medal, raised in commemoration of the visit of the British Association to South Africa in 1905, in accordance with the resolution of the Council.

(b) This resolution reads as follows :—

(1) That, in accordance with the wishes of subscribers, the South Africa Medal Fund be invested in the names of the Trustees appointed by the South African Association for the Advancement of Science.

(2) That the Dies for the Medal be transferred to the Association to which, in its corporate capacity, the administration of the Fund and the award of the Medal shall be, and is hereby, entrusted, under the conditions specified in the Report to the Medal Committee.

(c) The terms of conveyance are as follows :—

(1) That the Fund be devoted to the preparation of a Die for a Medal, to be struck in Bronze, $2\frac{1}{2}$ inches in diameter; and that the balance be invested and the annual income held in trust.

(2) That the Medal and income of the Fund be awarded by the South African Association for the Advancement of Science for achievement and promise in scientific research in South Africa.

(3) That, so far as circumstances admit, the award be made annually.

(d) The British Association has expressed a desire that the award shall be made only to those persons whose scientific work is likely to be usefully continued by them in the future.

III.—Awards.

(a) Any individual engaged in scientific research in South Africa shall be eligible to receive the award.

(b) The Medal and the available balance of one year's income from the funds shall be awarded to one candidate only in each year (save in the case of joint research); to any candidate once only; and to no member of the Medal Committee.

(c) Nominations for the recipient of the award may be made by any Member of the South African Association for the Advancement of Science, and shall be submitted to the Medal Committee not later than six months after the close of the Annual Session.

(d) The Medal Committee shall select, by a majority of the votes of its members, one candidate from amongst those nominated. For the purpose of securing this majority, the Chairman of the Committee shall have, if necessary, a casting vote. The Committee shall then vote as to whether the scientific work of the selected candidate is of sufficient merit and promise to justify the award, and, provided a majority of at least three-fourths of the members is obtained, shall recommend this candidate to the Council as the recipient of the award. The votes of the Committee shall be given by secret ballot. The recommendation of the Committee shall be submitted to the Council at least one month prior to the Annual Session.

(e) The award shall be made by the full Council of the South African Association for the Advancement of Science after considering the recommendation of the Medal Committee, provided it is carried by a vote of a majority of its Members, given in writing or verbally.

(f) The Council shall have the right to withhold the award in any year. The income for that year from the funds shall in such event be added to the capital of the Medal Fund.

(g) No alteration shall be made in these Rules, except under the condition specified in Clause 39 of the Association's Constitution, reading :—

Any proposed alteration of the Rules—

a. Shall be intimated to the Council three months before the next Session of the Association.

b. Shall be duly considered by the Council, and be communicated by circular to the Members of the Association for their consideration, and dealt with at the said Session of the Association.

(h) Should a member of the Medal Committee accept nomination for the Award, or be absent from South Africa at any time within four months before the commencement of the ensuing Annual Session, he will, *ipso facto*, forfeit his seat on the Committee.

42. The British Association Medal.

The British Association for the Advancement of Science has established a Research Medal and Grant in commemoration of its visit to South Africa in 1929. The conditions governing the award of this Medal and Grant are as follows :—

(a) The Medal shall be known as the British Association Medal and shall be open for competition annually.

(b) The Medal and Grant shall be awarded on the result of researches undertaken solely by the candidate and embodied in a paper presented at an Annual Meeting of the South African Association for the Advancement of Science.

(c) The competition is open only to Members of the South African Association for the Advancement of Science, whose age shall not exceed thirty years at the date of the Annual Meeting at which the paper is submitted. No candidate shall be eligible to receive more than one award.

(d) Candidates desirous of competing for the Medal and Grant must submit their papers in duplicate* to the Recorder of the Section at the commencement of the Annual Session and at the same time must notify the Honorary General Secretary of their intention of competing for the Medal and supply him, in writing, with a staatement of their age and the conditions under which the research was carried out.

(e) The Sectional Committees of the Sections, to which any papers in this competition have been submitted, will report on the merits of any papers so submitted and, in the event of more than one paper being submitted to any Section, will decide the order of merit of the papers.

(f) Those three papers, which, on the report of the above Committees, are judged of the highest merit by the Council of the South African Association, shall then be transmitted, not later than the end of October, to the Secretary of the British Association for final adjudication by the Council of that Association with a request that their decision be transmitted not later than the first day of May in each year.

(g) The successful candidate shall be informed of the result as soon as possible thereafter with a request that he or she be present at the next Annual Meeting in July to receive the Medal and Grant.

(h) If in its opinion it be necessary, the Council shall make an additional grant not exceeding £10 towards the expenses of the successful candidate involved in attending the Annual Meeting.

(i) In the event of the Grant not being awarded in any one year the amount available for the award for that year shall be added to the capital sum held in trust for this purpose by the Association.

BY-LAWS.

Sections of the Association.

1. The Scientific Work of the Association shall be transacted under such Sections as shall be constituted from time to time by the Council, and the constitution of such Sections shall be published in the Journal.

2. The Sections shall deal with the following Sciences and such others as the Council may add thereto from time to time :—Agriculture and

* Except that, in the case of numerous detailed drawings, done by hand only one set of drawings need be submitted.

Forestry; Anthropology and Ethnology; Archæology; Architecture; Anatomy; Astronomy; Bacteriology; Botany; Chemistry; Economics; Education; Engineering; Eugenics; Geodesy and Surveying; Geography; Geology and Mineralogy; History; Hygiene; Irrigation; Mathematics; Metallurgy; Meteorology; Philology; Physics; Physiology; Psychology; Sanitary Science; Sociology; Statistics; Zoology.

Sectional Committees.

3. The Sectional Committee shall consist of a President, two Vice-Presidents, two or more Secretaries, and such other persons as the Council may consider necessary, who shall be elected by the Council annually, after due consideration has been given to any recommendations of the previous Sectional Committees. Of the Secretaries, at least one (who shall, if possible, be resident in or near the Headquarters of the Association) shall act as Recorder of the Section, and at least one shall, whenever possible, be resident in the Centre where the Annual Session is to be held.

4. From the time of their election, which shall take place as soon as possible after the Session of the Association, they shall form themselves into an Organising Committee for the purpose of obtaining information upon Papers likely to be submitted to Sections, and for the general furtherance of the work of the Sectional Committees.

5. The Sectional Committees shall have power to add to their number from among the Members of the Association.

6. The Committees of the several Sections shall determine the acceptance of Papers before the beginning of the Session, keeping the General Secretaries informed from time to time of their work. In order to give an opportunity to the Committees of doing justice to the several communications, each Author must, except under very special circumstances, prepare an Abstract of his Paper, and must send it, together with the original Paper, to the Recorder of the Section before which it is to be read, so that it may reach the Recorder at least a fortnight before the Session. Papers should be condensed and limited as far as possible to the description or discussion of new facts, new observations or new ideas. They should be typewritten and carefully corrected. The heading of every paper must contain the Author's name, degrees, and title or official position. Papers and discussions thereon may be in either of the official languages of the Union.

Illustrations (other than photographs and half-tones) accompanying papers intended for publication in the Association's JOURNAL must be supplied by the Authors, carefully drawn about twice the size of the finished block, on smooth white Bristol board, in Indian ink, so as to admit of the blocks being prepared directly from the drawings. Any lettering on these drawings should be of such a size that it will be clearly legible when reduced. For graphs squared paper ruled in pale blue only should be used, otherwise the ruled squares appear black in the photographic reproduction. The size of the printing area of a page of the Association's JOURNAL, including space for legends, is 7in. × 4in.

7. Members may communicate to the Sections the Papers of non-members, provided that before such papers are published in the JOURNAL the Council may require that the authors shall either become members of the Association or contribute to the cost of printing.

8. The Author of any Paper is at liberty to reserve his right of property therein, but Papers accepted for publication in the *South African Journal of Science*, after having been read at an Annual General Meeting, must not be offered to any other Journal, unless arranged otherwise with the Council in advance.

9. The Sectional Committees shall meet not later than the first day of the Session in the Rooms of their respective Sections, and prepare the programme for their Sections, and forward the same to the General Secretaries for publication.

10. The Council cannot guarantee the insertion of any Report, Paper or Abstract in the Annual Volume unless, after reading, it is handed to the Recorder or Secretary of the Section before the conclusion of the Session.

11. The Sectional Committee shall report to the Council what Reports, Papers or Abstracts it is thought advisable to print, but the final decision shall rest with the Council.

Duties of Sectional Officers and Committees.

12. The attention of all Sectional Officers is directed to By-Laws 3 to 11, relating to the Sectional Committees and their functions.

13. The President and Recorder (or Secretary) of a Section shall have power during the Annual Session to act on behalf of the Section in any matter of urgency which cannot be brought before the consideration of the whole Sectional Committee; and they shall report such action to the next meeting of the Sectional Committee.

14. The President of the Section or, in his absence, one of the two Vice-Presidents, shall preside at all meetings of the Section or of the Sectional Committee.

15. The President of the Section is expected to prepare a Presidential Address, which shall be delivered personally during the Annual Session.

16. Prior to the commencement of the Session, the Recorder of each Section shall prepare a list of all Papers notified to be read during the Session, and shall also keep the Assistant General Secretary of the Association informed of the titles and Authors of all such Papers. The Assistant General Secretary shall, on his part, keep the Recorder informed of all Papers that may be notified to him direct. It would greatly facilitate the work of the Sections if the Recorders would read over the Papers sent in, before the beginning of the Annual Session, so as to advise Authors, if possible, as to any necessary amendments to their Papers.

17. When a proposal is made for the reading of a Paper at a joint meeting of Sections, the President, Recorder and Secretary of each Section shall *ex officio*, attend a meeting convened by a General Secretary to consider the same.

18. During the continuance of the Annual Session, the Recorder or Secretary of each Section shall be responsible for the punctual transmission to the Assistant General Secretary of the daily programme of his Section for early publication, and of any other recommendations adopted by the Sectional Committee; and shall at the close of the Session furnish the Editor with a list, showing which of the Papers notified for reading before the Section have been so read, and which have been taken as read, and giving the dates in either case. He shall, at the same time, indicate, giving reasons, the recommendations of the Sectional Committee with respect to each Paper, *i.e.*, whether it should be printed in full, or in abstract, or by title only.

19. Each Sectional Committee shall cause to be prepared a record of the discussion on each Paper read at its meeting; and such record shall be attached to the Paper and handed in with the same in terms of By-Law 22.

20. Each Sectional Committee shall, during the continuance of the Annual Session, meet daily, unless otherwise determined, to complete the arrangements for the next day.

21. In deciding on any recommendations regarding the printing or otherwise of a Paper submitted to it. the Sectional Committee shall consider only the merits of the Paper, and not the financial condition of the Association.

22. The Recorder or Secretary of each Section shall, at the close of each day, collect the Papers that have been read and hand them, together with a note explaining the cause of absence of any Paper not so handed over, to the Assistant General Secretary for transmission to the Editor.

23. Sectional Officers shall do their utmost to ensure punctual commencement and termination of the Section's daily proceedings; and, in drafting the programme for the next day, the Committee shall endeavour to allot a specified time to the reading and discussion of each Paper, in order to prevent other Sections, or the Association as a whole, being inconvenienced in consequence of delays.

Research Committees.

24. Grants may be made by the Association to Committees or to individuals for the promotion of scientific research.

25. Every proposal for special research, or for a grant of money in aid of special research, shall primarily be considered by the Sectional Committee dealing with the science specially concerned, and if such proposal be approved, shall be referred to the Council.

26. A Sectional Committee may recommend to Council the appointment of a Research Committee, composed of Members of the Association, to conduct research or to administer a grant in aid of research.

27. In recommending the appointment of Research Committees, the Sectional Committee shall specificially name all Members of such Committees; and one of them, who has notified his willingness to accept the office, shall be appointed to act as Secretary. The number of Members appointed to serve on a Research Committee shall be as small as is consistent with its efficient working.

28. All recommendations adopted by Sectional Committees shall be forwarded without delay to the Council for consideration and decision.

29. Reesarch Committees shall be appointed for one year only, but if the work of a Research Committee cannot be completed in that year, application may be made, through a Sectional Committee, at the next Annual Session, for re-appointment, with or without a grant—or a further grant—of money.

30. Every Research Committee, and every individual, to whom a grant has been made, shall present to the following Annual Meeting a report of the progress which has been made, together with a statement of the sums which have been expended. Any balance shall be returned to the General Treasurer.

31. In each Research Committee, the Secretary thereof shall be the only person entitled to call on the Treasurer for such portions of the sums granted as may from time to time be required.

Local and Reception Committees.

32. A Local Committee shall be constituted for the Centre at which the Annual Session is to be held, and shall consist of the Members of the Council resident in that Centre, with such other Members of the Association as the said Members of Council may elect.

33. The Local Committee shall form a Reception Committee to assist in making arrangements for the reception and entertainment of visitors. Such Reception Committee may include persons not necessarily Members or Associates of the Association.*

34. The Local Committee shall be responsible for all expenses in connection with the Annual Session of the Association.

Affiliation of Scientific and Kindred Societies.

By-Laws under which the O.F.S. Philosophical Society was incorporated from 1st July, 1914, with the South African Association for the Advancement of Science, with the designation of "The Orange Free State Branch" of the Association.

35. The O.F.S. Philosophical Society shall be incorporated with the South African Association for the Advancement of Science, this being the only course of procedure open under the existing Constitution.

(a). The Title of the Society so incorporated shall be "The Orange Free State Branch of the South African Association for the Advancement of Science.

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* The Reception Committee should make arrangements to provide:—

(1) A large hall for the delivery of the Presidential Address and evening lectures.

(2) A large room to be used as a Reception Room for members and others, at which all information regarding the Association can be obtained, and which shall have attached to it two Secretaries' Offices, a Writing Room for members and others, a Smoking Room, and Ladies' Room.

(3) Six rooms, each capable of accommodating about 30 or 40 people, to be used as Sectional Meeting Rooms, and, if possible, to have rooms attached, or in close proximity, for the purpose of holding meetings of Sectional Committees.

(4) Other requirements, such as office furniture, blackboards, window-blinds to darken Sectional Meeting Rooms for Lantern Lectures, notice-boards, etc.

(b). All Members of the South African Association for the Advancement of Science resident in the Orange Free State will, for the purpose of these By-Laws, be considered Members of the Orange Free State Branch of the Association.

(c). The Local Committee of the Branch shall consist of the Council Members of the Association for the Orange Free State, together with such additional members as the Branch may elect to serve on its Local Committee.

(d). Subscription notices to Members of the Branch shall be circulated from the Head Office of the Association in Johannesburg, and subscriptions shall be paid to the General Treasurer of the Association at Johannesburg, 10 per cent. thereof being remitted to the Orange Free State Branch for local expenses. Subscriptions of £1 10s. per annum shall entitle to membership of the Association as a whole, as well as of the Orange Free State Branch.

(e). All Members at present on the books of the Orange Free State Philosophical Society shall be entitled to become Members of the Association, to receive its JOURNAL, and to enjoy the full privileges of membership, as soon as their subscriptions for the financial year 1914-15 shall have been paid.

(f). Papers read before the Orange Free State Branch may either (1) be printed by title, abstract, or *in extenso*, in the JOURNAL of the Association for the current year, after reference to the Presidents of the respective Sectional Committees, or (2) be read at the next Annual Session of the Association (provided that they have not been previously published in abstract or *in extenso)*, and thereafter printed in the Association's JOURNAL, subject to the ordinary conditions.

36. Philosophical and Scientific Societies, and other Associations of a kindred character may, on application to, and with the approval of the Council, affiliate with the South African Association for the Advancement of Science on the following conditions :—

(a). That as a Society can only be affiliated on the approval of the Council, no minimum of membership of such Society need be specified.

(b). That each Society shall pay the Association a minimum fee of £5 for a strength of 50 members or less, and a further £1 for each additional 10 or portion of 10 members.

(c). That such Society shall be entitled to one copy of the *South African Journal of Science* for each £1 10s. paid to the Association.

(d). That such Society may, if it has a strength of 50 members, be represented on the Council of the Association by its President or such other member as may be nominated for the purpose.

(e). That all members of affiliated Societies may join the Association as ordinary members, with full privileges.

(f). That affiliated Societies shall be asked to take into consideration the admission of Members of the Association into their Societies at a reduced subscription.

(g). That Papers contributed to affiliated Societies may, on recommendation of both their own Council and that of the Association, be printed in the Association's JOURNAL OF SCIENCE, after which the Authors shall be entitled to reprints on the usual terms.

PRESIDENTS OF THE ASSOCIATION
FROM ITS FOUNDATION.

Sir DAVID GILL, K.C.B., LL.D., F.R.S., F.R.S.E.	Cape Town	April 27, 1903.
Sir CHARLES METCALFE, Bart, M.I.C.E.	Johannesburg	April 4, 1904.
THEODORE REUNERT, M.I.C.E., M.I.M.E.	Johannesburg	August 28, 1905.
GARDNER F. WILLIAMS, M.A.	Kimberley	July 9, 1906.
JAMES HYSLOP, D.S.O., M.B., C.M.	Durban	July 16, 1907.
H.E. Hon. Sir WALTER HELY-HUTCHINSON, G.C.M.G., LL.D.	Grahamstown	July 6, 1908.
H.E. Sir HAMILTON GOOLD-ADAMS, G.C.M.G., C.B.	Bloemfontein	September 27, 1909.
THOMAS MUIR, C.M.G., M.A., LL.D., F.R.S., F.R.S.E.	Cape Town	October 31, 1910.
Professor PAUL DANIEL HAHN, M.A., Ph.D.	Bulawayo	July 3, 1911.
ARNOLD THEILER, C.M.G., D.Sc.	Port Elizabeth	July 1, 1912.
ALEXANDER W. ROBERTS, D.Sc., F.R.A.S., F.R.S.E.	Lourenço Marques ...	July 7, 1913.
Professor RUDOLF MARLOTH, M.A., Ph.D.	Kimberley	July 6, 1914.
ROBERT T. A. INNES, F.R.A.S., F.R.S.E.	Pretoria	July 5, 1915.
Professor LAWRENCE CRAWFORD, M.A., D.Sc., F.R.S.E.	Maritzburg	July 3, 1916.
Professor JOHN ORR, B.Sc., M.I.C.E., M.I.Mech.E.	Stellenbosch	July 2, 1917.
CHARLES F. JURITZ, M.A., D.Sc., F.I.C.	Johannesburg	July 8, 1918
Rev. WILLIAM FLINT, D.D.	Kingwilliamstown ...	July 7, 1919.
ILLTYD BULLER POLE EVANS, M.A., D.Sc., F.L.S.	Bulawayo	July 14, 1920.
Professor J. E. DUERDEN, M.Sc., Ph.D., A.R.C.S	Durban	July 11, 1921.
ARTHUR W. ROGERS, Sc.D., M.A., F.R.S.	Lourenço Marques ...	July 10, 1922.
Professor J. D. F. GILCHRIST, M.A., D.Sc., Ph.D.	Bloemfontein	July 9, 1923.
Professor J. A. WILKINSON, M.A., F.C.S., M.I.Chem.E.	Cape Town	July 7, 1924.
General the Rt. Hon. J. C. SMUTS, K.C., P.C., C.H., LL.D., M.L.A.	Oudtshoorn	July 6, 1925.
E. T. MELLOR, D.Sc., F.G.S., M.I.M.M.	Pretoria	July 5, 1926.
Professor H. B. FANTHAM, M.A., D.Sc.	Salisbury	June 29, 1927.
Sir CARRUTHERS BEATTIE, D.Sc., LL.D.	Kimberley	June 20, 1928.
Hon. J. H HOFMEYR, M.A., D.Sc.	Johannesburg-Cape Town	July 22, 1929.
H. E. WOOD M.Sc., F.R.A.S.	Caledon	July 7, 1930.
Professor J. W. BEWS, M.A., D.Sc.	Grahamstown	July 6, 1931.
Professor P. J. DU TOIT, B.A., D.Phil., Dr.Med.Vet., D.Sc.	Durban	July 4, 1932.
ROBERT BROOM, M.D., C.M., D.Sc., F.R.S.	Barberton	July 3, 1933.
A. L. DU TOIT, B.A., D.Sc., F.G.S.	Port Elizabeth	July 2, 1934.
M M. RINDL, Ing.D.	Paarl	July 1, 1935.
H.E. the Rt. Hon. the EARL OF CLARENDON, P.C., G.C.M.G., Governor-General of the Union of South Africa	Johannesburg	October 5, 1936.
Lt.-Col. C. GRAHAM BOTHA, V.D., M.A.	Windhoek	July 5, 1937.

PRESIDENTS AND SECRETARIES OF THE SECTIONS.

SECTION A.—ASTRONOMY, CHEMISTRY, MATHEMATICS. METEOROLOGY AND PHYSICS.

Date and Place.	Presidents.	Secretaries.
1903. Cape Town ...	Prof. P. D. Hahn, M.A., Ph.D.	Prof. L. Crawford.
1904. Johannesburg* .	J. R. Williams, M.I.M.M., M.Amer.I.M.E.	W. Cullen, R. T. A. Innes.
1906. Kimberley	J. R. Sutton, M.A.	W. Gasson, A. H. J. Bourne.
1907. Natal†	E. N. Neville, F.R.S., F.R.A.S., F.C.S.	D. P. Reid, G. S. Bishop.
1908. Grahamstown ...	A. W. Roberts, D.Sc., F.R.A.S., F.R.S.E.	D. Williams, G. S. Bishop.

ASTRONOMY, MATHEMATICS, PHYSICS, METEOROLOGY, GEODESY, SURVEYING, ENGINEERING, ARCHITECTURE AND IRRIGATION.

1909. Bloemfontein ...	Prof. W. A. D. Rudge, M.A.	H. B. Austin, F. Masey.
1910. Cape Town‡ ...	Prof. J. C. Beattie, D.Sc., F.R.S.E.	A. H. Reid, F. Flowers.
1911. Bulawayo	Rev. E. Goetz, S.J., M.A., F.R.A.S.	A. H. Reid, Rev. S. S. Dornan.
1912. Port Elizabeth .	H. J. Holder, M.I.E.E.	A. H. Reid.
1913. Lourenco Marques ...	J. H. von Hafe.	Prof. J. Orr, J. Van Gomes.
1914. Kimberley	Prof. A. Ogg, M.A., B.Sc., Ph.D.	Prof A. Brown, A. E. H. Dinham-Peren.
1915. Pretoria	F. E. Kanthack, M.I.C.E., M.I.M.E.	Prof. A. Brown, J. L. Soutter.
1916. Maritzburg	Prof. J. Orr, B.Sc., M.I.C.E.	Prof. A. Brown, P. Mesham.
1917. Stellenbosch ...	Prof. W. N. Roseveare, M.A.	Prof. A. Brown, L. Simons.
1918. Johannesburg ...	Prof. J. T. Morrison, M.A., B.Sc., F.R.S.E.	Prof. A. Brown, Prof. J. P. Dalton
1919. Kingwilliamst'n	W. Ingham, M.I.C.E., M.I.M.E.	Dr. J. Lunt, T. G. Caink, J. Powell.
1920. Bulawayo	H. E. Wood, M.Sc., F.R.A.S.	Prof. J. Orr, A. C. Jennings.
1921. Durban	J. Lunt, D.Sc.	Prof J. Orr, H. Clark.
1922. Lourenco Marques ...	M. A. Peres, D.Sc.	Prof. J. Orr, R. H. Fox.
1923. Bloemfontein ...	Prof. W. H. Logeman, M.A.	Prof. J. Orr, Prof. W. F. C. Arndt
1924. Cape Town ...	J. K. E. Halm, Ph.D., F.R.A.S.	Dr. J. S. van der Lingen, Dr. B. F. J. Schönland.
1925. Oudtshoorn ...	R. J. van Reenen, B.A.	Prof. J. Orr, E. F. Edmeades.
1926. Pretoria	Prof. P. G. Gundry, B.Sc., Ph.D.	Prof. J. Orr, G. W. Cox.
1927. Salisbury	A. C. Jennings, M.I.C.E.	Prof. J. Orr, N. P. Sellick.
1928. Kimberley	J. S. van der Lingen, B.A., Ph.D.	H. E. Wood, F. W. Jameson.
1930. Caledon	Prof. H. H. Paine, M.A., B.Sc.	Prof. J. Orr, R. L. Rosenberg.
1931. Grahamstown ...	H. L. Alden, M.Sc., Ph.D., F.R.A.S.	Prof. J. Orr, S. W. Watson.
1932. Durban	Prof. R. W. Varder, M.A.	Prof. J. Orr, Prof. H. Clark.
1933. Barberton	Prof. G. A. Watermeyer, B.A., A.R.S.M.	Prof. H. H. Paine.
1934. Port Elizabeth .	J. S. Paraskevopoulos, D.Sc., F.R.A.S.	Prof. H. H. Paine, T. H. James.
1935. Paarl	B. J. F. Schonland, O.B.E., M.A., Ph.D.	Prof. John Orr, D. B. Hodges.
1936. Johannesburg ...	E. J. Hamlin, D.Sc., M.Inst.C.E.	J. Burnard Bullock, A. E. H. Bleksley.
1937. Windhoek	A. C. Parry.	Prof. H. H. Paine.

SECTION B.—ANTHROPOLOGY, ETHNOLOGY, BACTERIOLOGY, BOTANY, GEOGRAPHY, GEOLOGY, MINERALOGY AND ZOOLOGY.

1903. Cape Town	R. Marloth, M.A., Ph.D.	Prof. A. Dendy.
1904. Johannesburg ...	G. S. Corstorphine, B.Sc., Ph.D., F.G.S.	Dr. W. C. C. Pakes, W. H. Jollyman.
1906. Kimberley	Thos. Quentrall, M.I.M.E., F.G.S.	C. E. Addams, H. Simpson.

CHEMISTRY, METALLURGY, MINERALOGY, ENGINEERING, MINING AND ARCHITECTURE.

1907. Natal	C. W. Methven, M.I.C.E., F.R.S.E., F.R.I.B.A.	R. G. Kirkby, W. Paton.
1908. Grahamstown ...	Prof. E. H. L. Schwarz, A.R.C.S., F.G.S.	Prof. G. E. Cory, R. W. Newman, J. Muller.

* Metallurgy added in 1904.

† Geography and Geodesy transferred to Section A and Chemistry and Metallurgy to Section B in 1907.

‡ Irrigation added in 1910 and Geography transferred to Section B.

CHEMISTRY, BACTERIOLOGY, GEOLOGY, BOTANY, MINERALOGY, ZOOLOGY, AGRICULTURE, FORESTRY, SANITARY SCIENCE.

Date and Place.	Presidents	Secretaries.
1909. Bloemfontein ...	C. F. Juritz, M.A., D.Sc., F.I.C.	Dr. G. Potts, A. Stead.

CHEMISTRY, GEOLOGY, METALLURGY, MINERALOGY AND GEOGRAPHY.

1910. Cape Town	A. W. Rogers, M.A., Sc.D., F.G.S.	J. G. Rose, C. F. Ayres.
1911. Bulawayo	A. J. C. Molyneux, F.G.S., F.R.G.S.	J. G. Rose, G. N. Blackshaw.
1912. Port Elizabeth ..	Prof. B. de St. J. van der Riet, M.A., Ph.D.	J. G. Rose, J. E. Devlin.
1913. Lourenço Marques ...	Prof. R. B. Young, M.A., D.Sc., F.R.S.E., F.G.S.	Prof. G. H. Stanley, Captain A. Graça.
1914. Kimberley	Prof. G. H. Stanley, A.R.S.M., M.I.M.E., M.I.M.M., F.I.C.	J. G. Rose, J. Parry.
1915. Pretoria	H. Kynaston, M.A., F.G.S.	Dr. H. C. J. Teitz, Prof. D. F. du Toit Malherbe.
1916. Maritzburg	Prof. J. A. Wilkinson, M.A., F.C.S.	Dr. H. C. J. Teitz, Prof. J. W. Bews.
1917. Stellenbosch ...	Prof. M. M. Rindl, Ing.D.	Dr. H. C. J. Teitz, Prof. B. de St. J. van der Riet.
1918. Johannesburg	P. A. Wagner, Ing.D., D.Sc.	Dr. H. C. J. Teitz, Dr. J. Moir.
1919. Kingwilliamst'n	H. H. Green, D.Sc., F.C.S.	Prof. J. A. Wilkinson, T. H. Harrison, W. G. Chubb.
1920. Bulawayo	F. P. Mennell, F.G.S., M.I.M.M.	J. M. Hutcheon, A. M. MacGregor.
1921. Durban	J. Moir, M.A., D.Sc., F.I.C.	Prof. J. A. Wilkinson, A. Kloot.
1922. Lourenço Marques ...	E. T. Mellor, D.Sc., F.G.S.	J. H. Wellington.
1923. Bloemfontein	A. Stead, B.Sc., F.C.S.	Prof. J. A. Wilkinson, Dr. W. von Bonde.
1924. Cape Town	A. L. du Toit, B.A., D.Sc.	Dr. C. F. Juritz, Dr. W. F. Barker.
1925. Oudtshoorn	B. de C. Marchand, B.A., D.Sc.	Dr. C. F. Juritz, Dr. W. F. Barker.
1926. Pretoria	St. C. O. Sinclair, M.A., D.Sc.	Dr. P. A. Wagner, W. Kupferburger.
1927. Salisbury	H. B. Maufe, M.A.	Prof. J. A. Wilkinson, A. W. Facer
1928. Kimberley	Prof. J. Smeath Thomas, D.Sc.	Prof. J. A. Wilkinson, J. Parry.
1930. Caledon	Prof. W. F. Barker, Ph.D., B.Sc.	Dr. J. Robertson, Dr. C. Juritz.
1931. Grahamstown ...	Prof. I. de V. Malherbe, B.A., Ph.D.	Dr. J. B. Robertson, Prof. E. D. Mountain.
1932. Durban	L. J. Krige, Ph.D.	Dr. J. B. Robertson, A. H. Kloot.
1933. Barberton	Jas. Gray, F.I.C.	Prof. F. J. Tromp.
1934. Port Elizabeth ..	J. B. Robertson, M.A., B.Sc., Ph.D.	Prof. G. H. Stanley, A. London.
1935. Paarl	Col. J. G. Rose, D.S.O., V.D., F.I.C.	Dr. J. B. Robertson, Prof. B. de St. J. van der Riet.
1936. Johannesburg ...	Prof. E. D. Mountain, M.A.	Dr. J. B. Robertson, Dr. B. Segal.
1937. Windhoek	Prof. J. H. Wellington, M.A.	Dr. B. Segal.

SECTION C.—AGRICULTURE, ARCHITECTURE, ENGINEERING, GEODESY, SURVEYING AND SANITARY SCIENCE.

1903. Cape Town	Sir Charles Metcalfe, Bart., M.I.C.E.	A. H. Reid.
1904. Johannesburg* ..	Lieut.-Colonel Sir Percy G. G. Girouard, K.C.M.G., D.S.O.	G. S. Burt Andrews, E. J. Laschinger.
1906. Kimberley	S. J. Jennings, C.E., M.Amer.I.M.E., M.I.M.E.	D. W. Greatbach, W. Newdigate.

BACTERIOLOGY, BOTANY, ZOOLOGY, AGRICULTURE AND FORESTRY, PHYSIOLOGY, HYGIENE.

1907. Natal	Lieut.-Col. H. Watkins-Pitchford, F.R.C.V.S.	W. A. Squire, A. M. Neilson, Dr. J. E. Duerden.
1908. Grahamstown ...	Prof. S. Schönland, M.A., Ph.D., F.L.S., C.M.Z.S.	Dr. J. Bruce Bays, W. Robertson, C. W. Mally, Dr. L. H. Gough.
1910. Cape Town† ...	Prof. H. H. W. Pearson, M.A., Sc.D., F.L.S.	W. D. Severn, Dr. J. W. B. Gunning.
1911. Bulawayo	F. Eyles, F.L.S., M.L.C.	W. T. Saxon, H. G. Mundy.
1912. Port Elizabeth ..	F. W. FitzSimons, F.Z.S., F.R.M.S.	W. T. Saxton, I. L. Drège.
1913. Lourenço Marques ...	A. L. M. Bonn, C.E.	F. Flowers, Lieut. J. B. Bothelho.
1914. Kimberley	Prof. G. Potts, M.Sc., Ph.D.	C. W. Mally, W. J. Calder.
1915. Pretoria	C. P. Lounsbury, B.Sc., F.E.S.	C. W. Mally, A. K. Haagner.
1916. Maritzburg	I. B. Pole Evans, M.A., B.Sc., F.L.S.	C. W. Mally, Prof. E. Warren.
1917. Stellenbosch ...	J. Burtt-Davy, F.L.S., F.R.G.S.	C. W. Mally, C. S. Grobbelaar.

* Forestry added in 1904.

† Sanitary Science added in 1910.

BOTANY, BACTERIOLOGY, AGRICULTURE AND FORESTRY.

Date and Place.	Presidents.	Secretaries.
1918. Johannesburg ...	C. E. Legat, B.Sc.	Dr. E. P. Phillips, P. Burtt-Davey.
1919. Kingwilliamst'n	Ethel M. Doidge, M.A., D.Sc., F.L.S.	Dr. E. P. Phillips, E. W. Dwyer, Dr. G. Rattray.
1920. Bulawayo	T. R. Sim, D.Sc., F.L.S.	Dr. E. P. Phillips, Prof. H. A. Wager.
1921. Durban	Prof. J. W. Bews, M.A., D.Sc.	Prof. H. A. Wager, Dr. H. F. Standing.
1922. Lourenço Marques ...	Prof. D. Thoday, M.A.	Prof. H. A. Wager.
1923. Bloemfontein ...	Prof. Bertha Stoneman, D.Sc.	Prof. G. Potts.
1924. Cape Town	Prof. R. H. Compton, M.A.	Miss M. R. Levyns, Miss E. L. Stephens.
1925. Oudtshoorn	E. Parish, B.Sc.	Dr. G. Potts, Dr. P. A. van der Bijl.
1926. Pretoria	Prof. P. A. van der Bijl, M.A., D.Sc.	Dr. E. P. Phillips, Dr. Ethel M. Doidge.
1927. Salisbury	Prof. R. S. Adamson, M.A., B.Sc.	Prof. C. E. B. Bremekamp, J. S. Henkel.
1928. Kimberley	J. S. Henkel.	Dr. E. M. Robinson, Dr. E. P. Phillips.
1930. Caledon	E. P. Phillips, M.A., D.Sc.	A. O. D. Mogg, Prof. N. J. G. Smith
1931. Grahamstown ...	Prof. N. J. G. Smith, M.A., Ph.D.	A. O. D. Mogg, Miss L. L. Britten.
1932. Durban	Prof. E. M. Robinson, Dr.Med.Vet., F.R.C.V.S.	Dr. E. M. Young, A. W. Bayer.
1933. Barberton	Prof. J. M. Hector, B.Sc.	Dr. V. A. Wager.
1934. Port Elizabeth ..	T. D. Hall, B.A., M.Sc.	Dr. E. M. Young, F. R. Long.
1935. Paarl	E. P. Phillips, M.A., D.Sc.	Prof. John Phillips, C. Cohen.
1936. Johannesburg ...	Prof. John Phillips, D.Sc., F.R.S.E., F.L.S.	R. A. Dyer, H. B. Gilliland.
1937. Windhoek	Miss M. Henrici, Ph.D.	Dr. E. P. Phillips, Dr. G. Bos.

SECTION D.—ZOOLOGY, PHYSIOLOGY, EUGENICS, HYGIENE AND SANITARY SCIENCE.

1918. Johannesburg	Prof. E. J. Goddard, B.A., D.Sc.	C. W. Mally, R. J. Ortlepp.
1919. Kingwilliamst'n	Prof. E. Warren, D.Sc.	C. W. Mally, Dr. J. I Brownlee, B. H. Dodd.
1920. Bulawayo	C. W. Mally, M.Sc., F.E.S.	Dr. Annie Porter, P. H. Taylor.
1921. Durban	Prof. H. B. Fantham, M.A., D.Sc.	Dr. Annie Porter, E. C. Chubb.
1922. Lourenço Marques	Annie Porter, D.Sc., F.L.S.	Prof. H. B. Fantham, C. B. Hardenberg.
1923. Bloemfontein ...	J. Hewitt, B.A.	Dr. Annie Porter, Dr. E. C. van Hoepen.
1924. Cape Town	Prof. E. H. Cluver, M.A., M.D.	Dr. Annie Porter, Dr. C. von Bonde.
1925. Oudtshoorn	Prof. J. E. Duerden, M.Sc., Ph.D.	Dr. Annie Porter, Miss N. F. Paterson
1926. Pretoria	Prof. C. G. S. de Villiers, M.A., Ph.D.	Prof. H. B. Fantham, Miss J. F. M. Schuurman.
1927. Salisbury	S. H. Skaife, M.A., M.Sc., Ph.D.	Dr. Annie Porter, R. W. Jack.
1928. Kimberley	Prof. P. J. du Toit, B.A., Ph.D., Dr.Med.Vet.	Dr. Annie Porter, J. H. Power.
1930. Caledon	E. L. Gill, D.Sc	Dr. Annie Porter, Dr. C. von Bonde.
1931. Grahamstown ...	C. von Bonde, M.A., Ph.D.	Dr. Annie Porter, Dr. S. F. Bush.
1932. Durban	R. Broom, M.D., D.Sc., F.R.S.	Dr. Annie Porter, Dr. S. F. Bush.
1933. Barberton	E. C. Chubb, F.Z.S.	G. G. Ulyett.
1934. Port Elizabeth .	J. H. Power, F.R.S. (S.A.), F.Z.S.	Prof. C. G. S. de Villiers, Dr. B. Smit.
1935. Paarl	Gertrude Theiler, D.Sc.	Dr. N. F. Paterson, G. P. du Toit.
1936. Johannesburg ...	R. Bigalke, M.A., Dr.Phil.	Dr. N. F. Paterson, Miss E. Strang.
1937. Windhoek	A. Roberts, D.Sc.	Dr. Gillman, V. F. Fitzsimons.

SECTION E.—ANTHROPOLOGY. ETHNOLOGY, ECONOMICS, SOCIOLOGY AND STATISTICS.

1903. Grahamstown ...	W. Hammond Tooke.	Prof. A. S. Kidd.

ANTHROPOLOGY, ETHNOLOGY, ARCHÆOLOGY, PHILOLOGY AND NATIVE SOCIOLOGY.

1917. Stellenbosch ...	Rev. N. Roberts.	Rev. E. W. H. Musselwhite, Prof. J. J. Smith.
1918. Johannesburg ...	Rev. W. A. Norton, B.A., B.Litt.	Rev. E. W. H. Musselwhite, Rev. G. Evans.
1919. Kingwilliamst'n	Rev. J. R. L. Kingon, M.A., F.R.S.E., F.L.S.	Rev. E. W. H. Musselwhite, G. R. Spencer, M. Flemmer.
1920. Bulawayo	Rev. H. A. Junod.	N. H Wilson, Rev. N. Jones.
1921. Durban	C. T. Loram, M.A., LL.B., Ph.D.	Rev. N. Roberts, F. E. Chandley.
1922. Lourenço Marques	Senator A. W. Roberts, D.Sc.	Rev. N. Roberts, Rev. H. L. Bishop.
1923. Bloemfontein ...	Prof. A. R. Radcliffe Brown, M.A.	Rev. N. Roberts, E. J. C. Stevens.
1924. Cape Town	W. G. Bennie, B.A.	Mrs. A. W. Hoernlé, Dr. D. M. Beach

SECTION E.—Continued.

Date and Place.	Presidents.	Secretaries.
1925. Oudtshoorn	Prof. R. A. Dart, M.Sc., M.B., Ch.M.	Mrs. A. W. Hoernlé, C. H. Heese.
1926. Pretoria	J. D. Rheinallt Jones.	Mrs. A. W. Hoernlé.
1927. Salisbury	Rev. N. Jones, F.R.A.I., F.E.S.	Mrs. A. W. Hoernlé, G. A. Taylor.
1928. Kimberley	Prof. T. T. Barnard, M.A., Ph.D.	Dr. E. C. N. van Hoepen, C. van Riet Lowe.
1930. Caledon	C. van Riet Lowe, B.Sc.	Prof. L. F. Maingard, Dr. I. Schapera.
1931. Grahamstown	A. J. H. Goodwin, M.A.	Prof. L. F. Maingard, Dr. I. Schapera.
1932 Durban	Miss D. F. Bleek.	Prof. L. F. Maingard, Dr. F. G. Cawston.
1933. Barberton	Mrs. A. W. Hoernlé, B.A.	Dr. I. Schapera.
1934. Port Elizabeth .	Prof. L. F. Maingard, M.A., D.Lit.	Dr. A. Galloway, E. C. Hancock.
1935. Paarl	Prof. P. R. Kirby, M.A., D.Litt., F.R.C.M.	Dr. A. Galloway, Dr. J. A. Engelbrecht.
1936. Johannesburg ...	Prof. M. R. Drennan, M.A., M.B., Ch.B., F.R.C.S.E.	Prof. C. van Riet Lowe, Miss M. Orford.
1937. Windhoek	A. Galloway, M.A., M.B., Ch.B.	L. H. Wells.

SECTION F.—ARCHÆOLOGY, EDUCATION, MENTAL SCIENCE, PHILOLOGY, POLITICAL ECONOMY, SOCIOLOGY AND STATISTICS.

1903. Cape Town	Thomas Muir, C.M.G., M.A., LL.D., F.R.S., F.R.S.E.	Prof. H. E. S. Fremantle.
1904. Johannesburg ...	(Sir Percy Fitzpatrick, M.L.A.), E. B. Sargant, M.A. (Acting).	Howard Pim, J. Robinson.
1906. Kimberley	A. H. Watkins, M.D., M.R.C.S.	E. C. Lardner-Burke, E. W. Mowbray.

ANTHROPOLOGY, ARCHÆOLOGY, ECONOMICS, EDUCATION, ETHNOLOGY, HISTORY, PSYCHOLOGY, PHILOLOGY, SOCIOLOGY AND STATISTICS.

1907. Natal	R. D. Clark, M.A.	R. A. Gowthorpe, A. S. Langley, E. A Belcher.

ARCHÆOLOGY, EDUCATION, HISTORY, PSYCHOLOGY AND PHILOLOGY.

1908. Grahamstown ...	E. G. Gane, M.A.	Prof. W. A. Macfadyen, W. B. Neilson.

ANTHROPOLOGY, ETHNOLOGY, EDUCATION, HISTORY, MENTAL SCIENCE, PHILOLOGY, POLITICAL ECONOMY, SOCIOLOGY AND STATISTICS.

1909. Bloemfontein ...	Hugh Gunn, M.A.	C. G. Grant, Rev. W. A. Norton
1910. Cape Town	Rev. W. Flint, D.D.	G. B. Kipps, W. E. C. Clarke.
1911. Bulawayo	G. Duthie, M.A., F.R.S.E.	G. B. Kipps, W. J. Shepherd.
1912. Port Elizabeth ..	W. A. Way, M.A.	G. B. Kipps, E. G. Bryant.
1913. Lourenço Marques ...	J. A. Foote, F.G.S.	H. Pim, J. Elvas.
1914. Kimberley	Prof. W. Ritchie, M.A.	Prof. R. D. Nauta, A. H. J. Bourne.
1915. Pretoria	J. E. Adamson, M.A.	Prof. R. D. Nauta, R. G. L. Austin.
1916. Maritzburg	M. S. Evans, C.M.G., F.Z.S.	Prof. R. D. Nauta, Prof. O. Waterhouse.

EDUCATION, HISTORY, NATIVE EDUCATION, MENTAL SCIENCE, POLITICAL ECONOMY, GENERAL SOCIOLOGY AND STATISTICS.

1917. Stellenbosch ...	Rev. B. P. J. Marchand, B.A.	Prof. R. D. Nauta, Dr. Bertha Stoneman.
1918. Johannesburg ...	Prof. T. M. Forsyth, M.A., D.Phil.	Prof. R. D. Nauta, J. Mitchell.
1919. Kingwilliamst'n	Prof. R. Leslie, M.A., F.S.S.	Prof. R. D. Nauta, J. Wood, F. J. Cherrigh.
1920. Bulawayo	Prof. R. A. Lehfeldt, B.A., D.Sc.	J. Mitchell, B. M. Narbeth.
1921. Durban	Prof. W. A. Macfadyen, M.A., LL.D.	J. A. Foote, B. M. Narbeth.
1922. Lourenço Marques ...	J. M. Moll, M.D.	Mrs. Mabel Palmer.
1923. Bloemfontein ...	J. T. Dunston, M.D.	Mrs. M. Palmer, Prof. T. M. Forsyth.
1924. Cape Town	C. Graham Botha.	F. S. Livie-Noble, Dr. S. H. Skaife.
1925. Oudtshoorn	Prof. H. A. Reyburn, M.A., D.Phil.	Dr. S. H. Skaife, F. S. Livie-Noble.
1926. Pretoria	Samuel Evans, LL.D.	C. S. Richards, F. S. Livie-Noble
1927. Salisbury	Hon. W. M. Leggate, C.M.G., M.L.A.	Mrs. M. Palmer, Dr. M. Boehmke
1928. Kimberley	M Boehmke, M.A., Ph.D.	Mrs. M. Palmer, I. D. MacCrone

SECTION F.—Continued.

PSYCHOLOGY, EDUCATION, NATIVE EDUCATION, SOCIOLOGY, ECONOMICS, STATISTICS, HISTORY.

Date and Place.	Presidents.	Secretaries.
1930. Caledon	Mrs. M. Palmer, M.A.	I. D. MacCrone, C. Graham Botha.
1931. Grahamstown ...	Prof. R. W. Wilcocks, B.A., Ph.D.	I. D. MacCrone, Mrs. M. Palmer, Dr. E. H. Wild.
1932. Durban	Rev. Prof. J. du Plessis, D.D., Litt.D.	Mrs. M. Palmer, Dr. E. H. Wild, C. Axelson.
1933. Barberton	Prof. C. S. Richards, M.Com.	Miss E. Noël.
1934. Port Elizabeth	Miss H. P. Pollak, M.A.	Miss H. P. Pollak.
1935. Paarl	Prof. C. G. W. Schumann, B.Sc., D.Comm.	E. G. Pells.
1936. Johannesburg ...	Prof. I. D. MacCrone, M.A., D.Litt.	Miss H. P. Pollak, M. Pelkowitz.
1937. Windhoek	W. Russell, M.D., Ch.B., D.Psych.	Miss H. P. Pollak, Mrs. H. M. McKay.

EVENING DISCOURSES.

Date and Place.	Lecturer.	Subject of Discourse.
1903. Cape Town	Prof. W. E. Logeman, B.A., L.H.C.	The Ruins of Persepolis and how the Inscriptions were read.
1904. Johannesburg ...	H. S. Hele-Shaw, LL.D., F.R.S., M.I.C.E.	Road Locomotion—Present and Future.
1906. Kimberley	Prof. R. A. Lehfeldt, B.A., D.Sc.	The Electrical Aspect of Chemistry.
	W. C. C. Pakes, L.R.C.P., M.R.C.S., D.P.H., F.I.C.	The Immunisation against Disease of Micro-organic Origin.
1907. Maritzburg	R. T. A. Innes, F.R.A.S., F.R.S.E.	Some Recent Problems in Astronomy.
Durban	Prof. R. B. Young, M.A., B.Sc., F.R.S.E., F.G.S.	The Heroic Age of South African Geology.
1908. Grahamstown ...	Prof. G. E. Cory, M.A.	The History of the Eastern Province.
	A. Theiler, C.M.G.	Tropical and Sub-tropical Diseases of South Africa.
1909. Bloemfontein ...	C. F. Juritz, M.A., D.Sc., F.I.C.	Celestial Chemistry.
	W. Cullen.	Explosives: their Manufacture and Use.
Maseru	R. T. A. Innes, F.R.A.S., F.R.S.E.	Astronomy.
1910. Cape Town	Prof. H. Bohle, M.I.E.E.	The Conquest of the Air.
1911. Bulawayo	J. Brown, M.D., C.M., F.R.C.S., L.R.C.S.E.	Electoral Reform—Proportional Representation.
	W. H. Logeman, M.A.	The Gyroscope.
1912. Port Elizabeth ..	A. W. Roberts, D.Sc., F.R.A.S.	Imperial Astronomy.
	Prof. E. J. Goddard, B.A., D.Sc.	Antarctica.
1913. Lourenço Marques ...	S. Seruya.	The History of Portuguese Conquest and Discovery.
1914. Kimberley	Prof. E. H. L. Schwarz, A.R.C.S., F.G.S.	The Kimberley Mines: their Discovery and their Relations.
1915. Pretoria	E. T. Mellor, D.Sc., F.G.S., M.I.M.M.	The Gold-bearing Conglomerates of the Witwatersrand.
	C. W. Mally, M.Sc., F.E.S., F.L.S.	The House Fly under South African conditions.
1916. Maritzburg	C. P. Lounsbury, B.Sc., F.E.S.	Scale Insects and their Travels.
Durban	R. T. A. Innes, F.R.A.S., F.R.S.E.	Astronomy.
1917. Stellenbosch ...	H. E. Wood, M.Sc., F.R.Met.S.	Some Unsolved Problems of Astronomy.
	Prof. J. D. F. Gilchrist, M.A., D.Sc., Ph.D., F.L.S.	Some Marine Animals of South Africa.
1918. Johannesburg ...	Prof. H. B. Fantham, M.A., D.Sc.	Evolution and Mankind.
	Prof. J. E. Duerden, M.Sc., Ph.D.	Ostriches.
1919. Kingwilliamst'n	Prof. E. J. Goddard, B.A., D.Sc.	The Approaching South African Antarctic Expedition.
East London ...	Prof. G. E. Cory, M.A.	Early History of Kaffraria and East London.
1920. Bulawayo	Prof. J. A. Wilkinson, M.A., M.I.Chem.E.	The Nitrogen Problem.
1921. Durban	A. L. du Toit, D.Sc., F.G.S.	Land Connections between other Continents and S. Africa in Past.

EVENING DISCOURSES.—Continued.

Date and Place.	Lecturer.	Subject of Discourse.
1922. Lourenço Marques ...	C. Graham Botha.	The Early Development of South Africa.
1923. Bloemfontein ...	Sir Geo. Cory, D.Lit.	The Piet Retief-Dingaan Treaty.
	Rev. N. Roberts, M.C.	South African Birds and How to Study Them.
	Dr. Annie Porter, D.Sc.	Louis Pasteur (in commemoration of centenary of his birth).
1924. Cape Town	H. Spencer Jones, M.A., B.Sc.	Wireless Messages from the Stars.
1925. Oudtshoorn	Prof. R. A. Dart, M.Sc., M.B.	Some Fossilised South Africans.
	Dr. Annie Porter, D.Sc.	Thomas Henry Huxley (in commemoration of centenary of birth).
1926. Pretoria	Hon. J. H. Hofmeyr, M.A.	The Romance of Ægean Archæology.
1927. Salisbury	A. L. du Toit, D.Sc., F.G.S.	The Kalahari and some of its Problems.
1928. Kimberley	Prof. P. R. Kirby, M.A., F.R.C.M.	Primitive and Exotic Music.
1930. Caledon	S. H. Skaife, M.A., Ph.D.	Heredity.
1931. Grahamstown ...	Prof. R. H. Compton, M.A.	The National Parks of U.S.A.
1932. Durban	Gen. the Rt. Hon. J. C. Smuts, K.C., LL.D., F.R.S.	Climate and Man in Africa.
	Prf. B. de St. J. van der Riet, Ph.D.	Essential Oils.
1933. Barberton	B. F. J. Schonland, O.B.E., M.A., Ph.D.	Thunderstorms and Their Electricity.
1934. Port Elizabeth ..	Prof. N. J. G. Smith, M.A., B.Sc., Ph.D.	Fungi as Parasites or Partners of Cultivated Plants.
	Mrs. H. M. McKay.	William John Burchell in St. Helena.
1935. Paarl	Prof. P. J. du Toit, B.A., D.Sc., Dr.Med.Vet.	Viruses.
	Mrs. H. M. McKay.	William John Burchell: Scientist.
1936. Johannesburg ...	Prof. Leo. Fouche, B.A., Dr. en Ph. et Litt.	Johannesburg in South African History.
1937. Windhoek	Prof. H. H. Paine, M.A., B.Sc.	The Light of the Sun.

MEETINGS AT WINDHOEK, 1937.

On *Monday, 5 July, 1937*, registration of members took place and sectional meetings were begun at the Government Primary School, Windhoek.

At 10 a.m., there was a meeting of the Council.

At 11 a.m., the members of the Association were welcomed by His Honour Dr. Conradie, the Administrator of South-West Africa, and by the Mayor of Windhoek, Councillor John Meinert. Lt.-Col. C. Graham Botha, President of the Association, replied on behalf of the visiting members.

At 2.30 p.m., Mr. A. C. Parry, President of Section A, delivered his address on "The History of Land Survey in S.W.A."

At 8 p.m., the members assembled in the Hall of the S.W.A. Legislative Assembly where Lt.-Col. C. Graham Botha, President of the Association, delivered his address entitled "The Science of Archives in South Africa." A vote of thanks was proposed by His Honour the Administrator and seconded by Dr. Lemmer. The President then introduced Professor C. G. S. de Villiers to whom the South African Medal and Grant was presented by His Honour the Administrator, who also handed the British Association Medal to Mr. West. Dr. R. Elsdon-Dew, the other recipient of the Medal, was unable to be present.

On *Tuesday, 6 July*, at 9 a.m., Professor J. H. Wellington delivered the Presidential Address to Section B, on "Some Geographical Aspects of the Peopling of Africa."

At 2.30 p.m., Dr. M. Henrici, President of Section C, delivered an Address on "Transpiration and Water Supply of South African Plants."

At 8.15 p.m., a performance of the Nama Reed-Flute Dance, as well as Dances of the Herero and Berg-Dama tribes, organised by Captain Bowker, was given for the benefit of the members on the Show Ground, Windhoek.

On *Wednesday, 7 July*, in the forenoon, an excursion took place to the Government Experimental Farm at Neudam, 25 miles east of Windhoek, where the principal features of the Karakul industry were demonstrated and tea was offered to the members.

At 4 p.m., His Honour the Administrator and Mrs. Conradie were "at home" at Government House to the members of the Association.

At 8 p.m., Professor H. H. Paine gave a Popular Evening Discourse on "The Light of the Sun."

On *Thursday, 8 July*, at 9 a.m., Dr. Austin Roberts, President of Section D, gave his address on "The old Surviving Types of Mammals in South Africa."

At 11 a.m.. Professor P. R. Kirby, in the unavoidable absence of Dr. Galloway, read the Presidential Address to Section E, on "Man in Africa in the Light of Recent Discoveries."

At 2.15 p.m., the Thirty-fifth Annual General Meeting of the Association was held.

At 8.30 p.m., the Association attended a Civic Reception and Dance, given by the Mayor and Town Council of Windhoek, at the Grossherzog Hotel.

On *Friday, 9 July*, in the forenoon, a visit was paid by the members to the S.W.A. Breweries, where different phases of the industry were explained.

In the afternoon the members were motored to different points of interest in the town, visiting the Zoological Gardens for its collection of meteorites, the hot water springs, the Town Hall, and were finally entertained at the S.W.A. Breweries by the Directors and the Manager.

On *Saturday, 10 July*, a meeting of the newly-appointed Council was held.

OFFICERS OF LOCAL AND SECTIONAL COMMITTEES, WINDHOEK, 1937.

EXECUTIVE COMMITTEE.

Professor G. H. Stanley (Chairman), Professor T. W. Gevers, Jas. Gray, Professor P. R. Kirby, Professor L. F. Maingard, Professor John Orr, Professor John Phillips, Principal H. R. Raikes, Dr. H. E. Wood.

LOCAL COMMITTEE.

Consisting of members of Council of the S.W.A. Scientific Society: J. Meinert (Chairman), P. Barth, Studienrat H. Betzler, W. Stritter, J. S. Watt, E. Zelle, G. Kerby (Hon. Secretary).

RECEPTION COMMITTEE.

Consisting of members of the Town Council: J. Meinert (Mayor), L. Taljaard (Deputy-Mayor), S. Cohen (Councillor), W. Koch (Councillor), E. Sander (Councillor), G. Kerby (Town Clerk) (Hon. Secretary).

SECTIONAL OFFICERS AND COMMITTEES.

Section A.

President: A. C. Parry. *Recorder:* Professor H. H. Paine. *Committee:* Dr. H. L. Alden, Professor W. H. Logeman, Professor John Orr, Dr. J. S. Paraskevopoulos, Dr. H. E. Wood.

Section B.

President: Professor J. H. Wellington. *Vice-Presidents:* Professor E. D. Mountain, Professor S. J. Shand. *Recorder:* Dr. B. Segal. *Committee:* Jas. Gray, Dr. C. F. Juritz, Dr. B. de C. Marchant, G. O. Neser, Dr. C. Rimington, Professor M. M. Rindl, Dr. J. B. Robertson, Colonel J. G. Rose, Professor G. H. Stanley, Professor B. de St. J. van der Riet.

Section C.

President: Dr. M. Henrici. *Vice-President:* J. J. Kotze. *Recorder:* Dr. E. P. Phillips. *Secretary:* Dr. G. Boss. *Committee:* Professor R. H. Compton. Professor J. H. Neethling, Dr. L. Vervoerd, Professor G. Potts.

Section D.

President: Dr. Austin Roberts. *Vice-Presidents:* Dr. R. Bigalke, Dr. A. J. Hesse. *Recorder:* Dr. Gillman. *Secretary:* V. F. FitzSimons, *Committee:* Dr. R. Broom, Dr. L. Boonstra, Professor C. G. S. de Villiers, Professor P. J. du Toit, Professor J. C. Faure, Dr. E. L. Gill, Dr. A. C. Hoffman. Dr. T. J. Naude, Dr. R. J. Ortlepp, J. H. Power, Professor Gertrud Theiler.

Section E.

President: Dr. A. Galloway. *Vice-Presidents:* Professor M. R. Drennan, L. H. Wells. *Recorder:* L. H. Wells. *Committee:* Miss D. F. Bleek, Mrs. A. W. Hoernle, Professor P. R. Kirby, Dr. Lemmer, Professor L. F. Maingard.

Section F.

President: Dr. William Russell. *Vice-Presidents:* Mrs. H. M. McKay, A. S. MacIntyre. *Recorder:* Miss H. P. Pollak. *Committee:* Dr. M. Boehmke, Rev. Dr. W. Flint.

PROCEEDINGS OF THE THIRTY-FIFTH ANNUAL GENERAL MEETING OF MEMBERS, HELD AT THE GOVERNMENT PRIMARY SCHOOL, WINDHOEK, ON THURSDAY, 8th JULY, 1937, AT 2.15 P.M.

PRESENT: Lt.-Col. C. Graham Botha (President) in the Chair; Mr. P. Barth, Mr. H. Betzler, Miss D. F. Bleek, Mrs. K. Botha, Professor C. G. S. de Villiers, Professor D. J. du Plessis, Mr. C. Ferguson, Mr. V. Fitzsimons, Dr. E. E. Galpin, Dr. Miss M. Henrici, Mrs. L. Jeffreys, Dr. E. Jokl, Mr. G. Kerby, Professor P. R. Kirby, Dr. C. J. C. Lemmer, Professor L. F. Maingard, Mrs. H. M. McKay, Mr. J. Meinert, Dr. Miss M. G. Mes, Mr. G. O. Neser, Professor H. H. Paine, Mrs. H. M. Paine, Dr. E. P. Phillips, Mr. J. Pringle, Dr. Austin Roberts, Dr. William Russell, Miss S. N. Schoeman, Professor G. H. Stanley, Mr. W. H. G. Stritter, Professor Gertrud Theiler, Professor G. A. Watermeyer, Mr. L. H. Wells, Miss E. E. Wijers, Mr. E. Zelle, Dr. H. E. Wood (Honorary General Secretary), and Mr. H. A. G. Jeffreys (Assistant General Secretary).

Apologies for absence were received from Dr. M. Boehmke, Mr. E. C. Chubb and the Durban Members of Council, Professor R. A. Dart, Dr. A. Galloway, Mr. Jas. Gray, Dr. A. J. Hesse, Mr. J. H. Power, Professor M. M. Rindl and Col. J. G. Rose.

MINUTES.—The Minutes of the Thirty-fourth Annual General Meeting, held at Johannesburg on the 8th October, 1936, and printed an pages xxii-xxv of the Report of the Johannesburg Session (Volume XXXIII of the JOURNAL), were confirmed.

ANNUAL REPORT OF COUNCIL.—The Annual Report of the Council for the year 1936-1937, having been duly suspended on the notice board at the Government Primary School, was taken as read and adopted. This Report will be found on pp. xxv-xxvi of this issue.

REPORT OF THE HONORARY GENERAL TREASURER AND STATEMENT OF ACCOUNTS.—The Honorary General Treasurer's Report and Statement of Accounts for the year ended 31st May, 1937, having been duly suspended on the notice board at the Government Primary School, were taken as read and adopted (see pp. xxvii-xxxiii of this issue).

ELECTION OF OFFICERS FOR 1937-1938.—The following were elected:—

President: Professor L. F. Maingard.

Vice-Presidents: Professor G. H. Stanley.
Professor C. G. S. de Villiers.
F. G. Braithwaite.
Professor M. M. Rindl.

Hon. General Secretaries: Dr. C. F. Juritz and Dr. H. E. Wood.

Hon. General Treasurer: Jas. Gray.

Hon. Editor of Publications: Professor John Phillips.

Hon. Librarian: P. Freer.

COUNCIL MEMBERS.—The following were elected:—

I. TRANSVAAL.—S. B. Asher, R. Craib, Professor R. A. Dart, Dr. A. L. du Toit, Dr. A. Galloway, T. D. Hall, Dr. E. J. Hamlin, Professor P. R. Kirby, Professor C. van Riet Lowe, Professor I. D. MacCrone, Professor John Orr, Professor H. H. Paine, F. R. Paver, Miss H. P. Pollak, Dr. J. B. Robertson, Dr. B. Segal, Dr. R. A. Dyer,

Professor P. J. du Toit, Professor J. M. Hector, Dr. H. O. Monnig, Dr. E. P. Phillips, Dr. A. Pijper, Dr. Austin Roberts, Professor G. T. S. Eiselen.

II. Cape of Good Hope Province.—Dr. L. D. Boonstra, Rev. Dr. W. Flint, Dr. A. J. Hesse, G. W. Lyon, Dr. B. de C. Marchand, Col. J. G. Rose, Dr. C. von Bonde, Professor Gertrud Theiler, Professor L. Verwoerd, Dr. F. J. S. Anders, J. H. Power, Professor N. J. G. Smith, Dr. M. Boehmke, H. C. Gardham.

III. Orange Free State.—Mr. Justice F. E. T. Krause, Dr. A. C. Hoffman, Professor W. H. Logeman.

IV. Natal.—Principal J. W. Bews, E. C. Chubb, Professor H. Clark, H. H. Dodds, J. F. Schofield.

V. Southern Rhodesia.—Rev. N. Jones, H. B. Maufe.

Annual Meeting, 1938.—The invitation of the City Council of Pietermaritzburg for the Association to hold its Annual Session in that city in 1938 was accepted unanimously and enthusiastically.

South African Bushmen Reserve.—Professor L. F. Maingard said that the Council of the Association had appointed a Committee to give support to and, if necessary, co-operate with an existing Committee which had been formed with the object of establishing a Reserve for South African Bushmen. Closely related was the question of the Bushmen in South-West Africa, and he asked for the support of the people in that territory. He suggested that, as the matter was now being favourably considered by the Government, there was no necessity for this Committee to take any action, but he asked that the Committee should remain in existence for future possibilities. Mr. J. Meinert, speaking in German, supported the principle of the establishment of a Bushmen Reserve.

National Arbor Day.—The following resolution, proposed by Dr. E. P. Phillips and seconded by Professor L. F. Maingard, was carried unanimously: "That this Annual General Meeting of the South African Association for the Advancement of Science supports the endeavour of the various Transvaal Publicity Associations to establish a National Arbor Day in the Union." It was decided that the above resolution be communicated to the Pretoria and Johannesburg Publicity Associations.

International Biological Abstracts.—Professor C. G. S. de Villiers suggested, for the consideration of the incoming Council, that the Journal should be sent to the Publishers of International Biological Abstracts with the view of obtaining publication of abstracts of papers printed in the Journal.

Votes of Thanks.—On the motion of Professor L. F. Maingard, seconded by Professor C. G. S. de Villiers, it was agreed unanimously that the thanks of the Association be accorded to the following:—

To His Honour the Administrator for his kind encouragement and facilities afforded by the Administration and to Mrs. Conradie for her generous hospitality.

To His Worship the Mayor (Councillor J. Meinert), the Municipal Council, and the Mayoress and Deputy-Mayoress.

To the members of the Local Committee and the Reception Committee for the excellent arrangements for the meeting.

To the Director of Education and the Principal of the Government Primary School (Mr. I. J. le Roux) for the use of the school buildings.

To the ladies of the South-West African Scientific Society for their hospitality to the lady members of the Association.

To the ladies and gentlemen who kindly provided transport for the excursions.

To the Director of Posts and Telegraphs and the Postmaster for the postal facilities provided at the headquarters of the meeting.

To the Senior Veterinary Officer (Mr. M. M. Neser) and his assistants (Messrs. J. S. Watt and D. Thompson) for their organisation of the inspection of the farm Neudam.

To Capt. O. G. Bowker for organising theNama Reed Flute Dance and so affording members of the Association a unique opportunity of witnessing this historic dance.

To the Manager of the South-West Breweries, Limited, for the privilege of visiting the brewery and subsequent entertainment.

To the press for their services in reporting papers read at the meeting.

To the Committees of the following Clubs for the privileges extended to members: The Central Club, the Windhoek Golf Club, the Central Tennis Club, the Gardens Tennis Club.

To the Town Clerk (Mr. G. Kerby, Hon. Secretary of the Local and Reception Committees) for his valuable services in connection with the arrangements for the meeting.

A cordial vote of thanks was proposed to the President, Lt.-Col. C. Graham Botha, and was received with acclamation.

REPORT OF COUNCIL FOR THE YEAR ENDED 30TH JUNE, 1937.

1. OBITUARY: Your Council has to report the deaths of the following members:—Mr. George Bush, Mr. D. M. Eadie, Senator F. Ginsberg, Mr. E. J. Laschinger (Foundation and Life Member), Dr. R. N. Perrott, Mr. John Shore, Mr. J. W. Shores, C.M.G., Sir Arnold Theiler, K.C.M.G. (Past President and Life Member), Mr. D. J. van Niekerk, Sir John Wessels (Chief Justice of the Union of South Africa), Mr. G. A. Wilmot and Brigadier-General Sir J. Scott Wylie.

2. MEMBERSHIP: Since the last Report sixty-eight members have joined the Association, thirteen have died and twenty-four have resigned. The net increase, therefore, has been thirty-one. The following comparative table, as from the 1st July last year, shows the geographical distribution of membership:—

	1936.	1937.
Transvaal	330	362
Cape of Good Hope Province ...	221	218
Natal	73	78
Orange Free State	33	32
Southern and Northern Rhodesia ...	15	15
South-West Africa	3	3
Moçambique	7	6
Abroad	27	26
	709	740

The Council notes with pleasure that increased activities on the part of Local Centres have resulted in many industrial firms becoming Institutional Members.

3. THE KING: Your Council has to report that His Majesty King George VI. has graciously consented to become the Patron of the Association.

4. THE JOURNAL: Volume XXXIII of the *South African Journal of Science*, comprising the Report of the Johannesburg Meeting, consisted of 1,206 pages, numerous plates and text figures. It was published in June, 1937.

5. SOUTH AFRICA MEDAL AND GRANT: On the recommendation of the South Africa Medal Committee, consisting of Dr. H. E. Wood (Chairman), Sir J. Carruthers Beattie, Principal J. W. Bews, Professor L. Crawford, Dr. A. L. du Toit, Professor P. J. du Toit, Dr. A. C. Hoffman, Professor L. F. Maingard, Dr. E. P. Phillips, Dr. A. Pijper, Professor M. M. Rindl, Dr. C. von Bonde, your Council has awarded the South Africa Medal, together with a grant of £51 16s. 5d., to Professor C. G. S. de Villiers, M.A., Ph.D. The Secretary of the British Association has been notified of the award.

6. BRITISH ASSOCIATION MEDAL: In view of the fact that no award was made in 1935, and on the recommendation of the Council of the British Association, and without prejudice to future practice, two awards of the British Association Medal and Grant had been made for 1936, viz.: one to Ronald Elsdon Dew, M.D., Ch.B., for his paper "The Application of Blood-grouping to South African Ethnology," and one to Oliver West, B.Sc., for his paper "An Investigation of the Methods of Botanical Analysis of Pasture."

7. DONATION: The thanks of the Association are due to the Honourable the Minister of the Interior, Education and Public Health for a grant of £250 towards the expenses of the publication of the JOURNAL.

8. BIRD PRESERVATION: The Association was invited to appoint a representative on an International Committee for Bird Preservation. Dr. E. L. Gill was appointed.

9. Film Advisory Board: Professor P. R. Kirby was elected to represent the Association on the Film Advisory Board of South Africa.

10. Geometric Tortoise: The Administration of the Cape of Good Hope Province, acting on a resolution passed at the last Annual General Meeting, has approached various Municipalities with regard to the institution of sanctuaries for these interesting animals.

11. Cape Mountain Zebra: With regard to the resolution passed at the Paarl Meeting of the Association as to the desirability of preserving the rare Cape Mountain Zebra, it is gratifying to note that the Government have decided to establish a reserve in the Cradock District.

12. South African Bushmen: During the year the Association appointed a Committee to act in co-operation with other bodies desirous of bringing about the establishment of a Reserve for South African Bushmen. This Committee will present a report to the Annual Meeting at Windhoek.

13. Organisation of Research: The Sub-Committee appointed to consider the Organisation of Research in South Africa has held various meetings during the year. It is now understood that the Government has under consideration a comprehensive scheme in connection with this important matter.

14. The New Council: On the basis of Membership provided in the Constitution, Section 20, the number of members of Council assigned for the representation of each Centre during the remainder of the year should be distributed as follows:—

Transvaal—	
Witwatersrand	18
Pretoria	7
Outside	1
Cape of Good Hope Province—	
Cape Peninsula and outside	6
Stellenbosch and District	3
East London and Port Elizabeth	1
Grahamstown, Kingwilliamstown and District	1
Kimberley	1
Oudtshoorn	1
Natal—	
Pietermaritzburg and Durban	4
Outside	1
Orange Free State—	
Bloemfontein	2
Southern Rhodesia	2
Moçambique	1
	49

15. The Council wishes to place on record its appreciation of the valuable services and effective assistance rendered throughout the year by the Assistant General Secretary, Mr. H. A. G. Jeffreys, O.B.E.

G. H. STANLEY, Chairman of Council.

C. F. JURITZ, }
H. E. WOOD, } Hon. Gen. Secretaries.

REPORT OF THE HONORARY GENERAL TREASURER FOR YEAR ENDED 31st MAY, 1937.

The holding of the Annual Meeting in October last year delayed the printing of the JOURNAL, which was not completed before the closing of the Accounts on 31st May. It was necessary, therefore, to make allowance for the cost of printing, and this was estimated at £1,750, which is £589 more than the cost last year.

The other items of expenditure show little variation from previous years. The income shows a slight increase from subscriptions, and interest and donations amount to £475.

The final result is that the excess of expenditure for the year is £569, and the balance has been reduced from £632 to £62 16s.

It is obvious that, failing an increase in revenue, the expenditure on the JOURNAL in future will require to be considerably reduced and brought more into line with income.

(Signed) JAS. GRAY,
Honorary General Treasurer.

THE SOUTH AFRICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

BALANCE SHEET AT 31st MAY, 1937.

Liabilities.

	£	s.	d.	£	s.	d.
Sundry Creditors—						
Open Accounts	£191	4	5			
Provision for Printing of Journal	1,750	0	0			
Library Deposit	3	0	0			
Subscriptions paid in advance .	16	1	0			
				£1,960	5	5
Library Binding and Equipment—						
Balance at 31st May, 1936 ...	102	12	6			
Add—Interest on Library Endowment Fund	77	12	4			
	180	4	10			
Less—Expenditure during year	65	2	1			
				115	2	9
Revenue and Expenditure Account—						
Balance at 31st May, 1936 ...	632	1	3			
Less—Excess of Expenditure over Revenue for the year ended 31st May, 1937 ...	569	5	3			
				62	16	0
				2,138	4	2
Endowment Fund				3,062	11	5
Library Endowment Fund				2,164	11	6
South Africa Medal Fund				1,617	16	3
British Association Medal Fund				499	2	9
				£9,482	6	1

Assets.

	£	s.	d.	£	s.	d.
Cash—						
On Hand	£1	18	3			
At Bank	206	10	0			
At Post Office Savings Bank, with interest accrued	1,685	8	5			
At St. Andrew's Building Society, with interest accrued	67	6	3			
				£1,961	2	11
Sundry Debtors—						
Trustees — South Africa Medal Fund for expenses *re* 1937 award	10	19	11			
For Advertisements in Journal	80	0	0			
				90	19	11
Furniture—						
Balance at 31st May, 1936 ...	88	17	6			
Less—Depreciation	10	0	0			
				78	17	6
Medals on Hand				7	3	10
				2,138	4	2
Trustees' Endowment Fund— As per separate account				3,062	11	5
Library Endowment Fund— Investments as per separate account ...				2,164	11	6
Trustees—South Africa Medal Account— As per separate account				1,617	16	3
Trustees—British Association Medal Account— As per separate account				499	2	9
				£9,482	6	1

We have examined the books and vouchers of the South African Association for the Advancement of Science for the year ended 31st May, 1937, and certify that in our opinion the above Balance Sheet correctly sets forth the position of the affairs of the Association at the 31st May, 1937, according to the best of our information and the explanations given to us and as shown by the books.

Johannesburg, 25th June, 1937.

ALEX. AIKEN & CARTER, Auditors.

THE SOUTH AFRICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

REVENUE AND EXPENDITURE ACCOUNT FOR THE YEAR ENDED 31ST MAY, 1937.

Dr.

To Salaries			£225 0 0
,, Rent			48 0 0
,, JOURNAL Expenses		£1,750 1 6	
Less—			
Government Grant	£250 0 0		
Sales, Reprints and Advertisements .	72 3 2		
		322 3 2	
			1,427 18 4
,, Printing and Stationery ...			33 17 7
,, Stamps and Telegrams ...			25 15 9
,, Insurance—Fidelity Bond and Workmen's Compensation ..			4 16 6
,, Expenses—			
Annual Meeting, 1936 (balance)		196 9 8	
Annual Meeting, 1937 (on account)		28 9 6	
			224 19 2
,, Sundry General Expenses ...			12 16 8
,, Grants to Local Centres under Rule 35—			
Witwatersrand		29 18 0	
Cape Peninsula		10 2 0	
Durban and Pietermaritzburg		7 6 0	
Orange Free State		2 11 0	
			49 17 0
,, Depreciation on Furniture ...			10 0 0
,, Removal Expenses			7 0 0
			£2,070 1 0

Cr.

By Annual Subscriptions	£696 9 0	
,, Arrear Subscriptions	115 0 0	
,, Associates' Fees	37 0 0	
,, Students' Fees	16 5 6	
		£864 14 6
,, Interest—		
On Endowment Fund ...	125 11 10	
On Post Office Savings Bank Account	35 9 5	
		161 1 3
,, Donations—		
To cover cost of Annual Meeting and increased cost of JOURNAL—		
Transvaal Chamber of Mines .	300 0 0	
Johannesburg Municipality ...	100 0 0	
African Explosives and Industries, Ltd.	75 0 0	
		475 0 0
,, Balance, being excess of Expenditure over Revenue ...		569 5 3
		£2,070 1 0

THE SOUTH AFRICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

ENDOWMENT FUND.

REVENUE AND EXPENDITURE ACCOUNT FOR THE YEAR ENDED 31st MAY, 1937.

Dr.	£ s. d.	Cr.	£ s. d.
To Interest as per contra, transferred to General Fund	£125 11 10	By Interest received during the year	£125 11 10
,, Balance transferred to Accumulated Funds	22 12 0	,, Sale of publications—British Association Account	0 2 0
		,, Life Members' Subscriptions	22 10 0
	£148 3 10		£148 3 10

BALANCE SHEET AT 31st MAY, 1937.

Liabilities.			Assets.		
Accumulated Funds—			Investments in hands of Trustees—		
Balance at 31st May, 1936	£3,039 19 5		Capetown Municipality 3¾% Stock	£1,150 0 0	
Add—Amount transferred from Revenue and Expenditure Account	22 12 0	£3,062 11 5	Capetown Municipality 4% Stock	300 0 0	
			Capetown Municipality 5% Stock	240 0 0	
			Capetown Municipality 5% Stock	800 0 0	
			Port Elizabeth Municipality 3½% Stock	100 0 0	
			Cape of Good Hope Savings Bank, with interest accrued	464 18 9	£3,054 18 9
			Amount due from General Fund		7 12 8
		£3,062 11 5			£3,062 11 5

THE SOUTH AFRICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

LIBRARY ENDOWMENT FUND.

Dr. REVENUE AND EXPENDITURE ACCOUNT FOR THE YEAR ENDED 31st MAY, 1937. **Cr.**

To Balance transferred to Library Binding and Equipment Account	£77 12 4	By Interest received during the year	£77 12 4
	£77 12 4		£77 12 4

BALANCE SHEET AT 31st MAY, 1937.

Liabilities.		Assets.	
Accumulated Funds—		Investments—	
Balance at 31st May, 1936	£2,164 11 6	£2,000 City of Johannesburg 3½% Local Registered Stock—at cost	£1,970 0 0
		Cash at St. Andrew's Building Society— Savings Bank Account	194 11 6
	£2,164 11 6		£2,164 11 6

THE SOUTH AFRICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

SOUTH AFRICA MEDAL FUND.

REVENUE AND EXPENDITURE ACCOUNT FOR THE YEAR ENDED 31st MAY, 1937.

Dr.		Cr.	
To Expenses in connection with 1937 Award	£10 19 11	By Interest received during the year	£62 10 6
,, Amount of Award, 1937	51 10 7		
	£62 10 6		£62 10 6

BALANCE SHEET AT 31st MAY, 1937.

Liabilities.		Assets.		
Sundry Creditors—		Investments in hands of Trustees—		
1937 Award and Expenses	£62 10 6	Fixed Deposit, South African Permanent Mutual Building and Investment Society, with interest accrued	£1,431 0 9	
Accumulated Funds—		Post Office Savings Bank ...	249 6 0	
Balance at 31st May, 1936	1,617 16 3			£1,680 6 9
	£1,680 6 9			£1,680 6 9

THE SOUTH AFRICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

THE BRITISH ASSOCIATION MEDAL FUND.

Dr. REVENUE AND EXPENDITURE ACCOUNT FOR THE YEAR ENDED 31ST MAY, 1937. **Cr.**

To Balance transferred to Accumulated Funds	£16 17 6	By Interest received during the year	£16 17 6
	£16 17 6		£16 17 6

BALANCE SHEET AT 31ST MAY, 1937.

Liabilities.			Assets.	
Accumulated Funds—			Investments in hands of Trustees—	
Balance at 31st May, 1936 ...	£482 5 3		£450 Union of South Africa 3¾ per cent. Local Registered Stock 1948/58	£450 0 0
Add—Amount transferred from Revenue and Expenditure Account	16 17 6		Amount due from General Fund	49 2 9
		£499 2 9		
		£499 2 9		£499 2 9

REPORT OF THE HONORARY LIBRARIAN FOR THE YEAR 1936-37.

The Association's Library is housed in Room 22, First Floor, in the Library of the University of the Witwatersrand, Johannesburg.

HOURS OF OPENING.

Weekdays. Term: 8.30 a.m. to 7 p.m.
Vacation: 9 a.m. to 5 p.m.

Saturdays. Term: 8.30 a.m to 12.30 p.m.
Vacation: 9 a.m. to 12.30 p.m.

EXCHANGE OF PUBLICATIONS.—During the year the following names were added to the exchange mailing list:—

1. Fan Memorial Institute of Biology, Peiping.
2. Royal Canadian Institute, Toronto.
3. South Australian Museum, Adelaide.

DONATIONS.—Gifts of books have been received from the following:—

1. British Museum (Natural History):
   Instructions to Collectors, No. 3, Reptiles.
   Students' Index to the Collection of Minerals, 27th ed., 1936.
2. Oxford University Press:
   Leakey, L. S. B. The Stone Age Races of Kenya.
3. U.S. Bureau of Mines:
   Miscellaneous Publications of the Bureau.

NUMBER OF VOLUMES.—The Library now contains approximately 2,500 volumes.

NUMBER OF PERIODICALS.—The number of periodicals currently received is 272.

BINDING.—43 volumes were bound at a cost of £14 13s. 7d.

SUPPLEMENTARY CATALOGUE OF SERIAL PUBLICATIONS, 1933-37.

The following list is a cumulation of earlier supplements and should be used in conjunction with the Main Catalogue published in the 1933 (Barberton) volume.

Abbreviations and symbols used:—

+ indicates that the serial is currently received and that the set is complete from the last volume or number given.

[indicates that the volumes following are incomplete.

w. indicates that the volumes or numbers following are wanting.

Academia Nacional de Ciencias "Antonio Alzate." *Memorias y revista.* 49, 1928+ [49.

Academy of Natural Sciences of Philadelphia. Annual Report. 1920-21. *Proceedings.* 1, 1841+. Yearbook, 1927-32.

R. Accademia d'Italia. *Memorie. Classe di scienze fisiche matematiche e naturali.* 2, 1931+.

African Society. *See* Royal African Society.

American Journal of Botany. 1-21, 1916-34. [1, 16, 21. w. 2.

Archives Néerlandaises de Zoologie. 1, 1934+.

Archives of Medical Hydrology. [10, 1932; 14, 1936+.

Association Française pour l'Avancement des Sciences. *See also* Sciences. *Comptes rendus.* 57, 1933+.

Bloemfontein. Nasionale Museum. *Soölogische Navorsing.* 1, 1935+.

Brooklyn Botanic Garden. *Contributions.* Nos. 1-64, 1911-32. w. 12. *Leaflets* [1-21, 1913-33. *Memoirs* 1-3 1918-27. *Record* [1-20, 1912-31; 21-22, 1932-33.

Brussels. Jardin botanique de l' état. *Bulletin.* 3, 1910+. [3, 8, 10, 11.

Brussels. Musée Royal d'Histoire Naturelle de Belgique. *Bulletin* 6, 1930+. *Mémoires* No. 47, 1931+. *Mémoires. Hors série* 1, 1930+. *Mémoires* 2e série, 1, 1936+.

California. University of California at Los Angeles. Publications. *Biological Sciences.* 1, 1933+.

Canadian Institute, Toronto. *See* Royal Canadian Institute.

Canadian Journal of Science, Literature and History. *Formerly* Canadian Journal. Continued as Royal Canadian Institute. *Proceedings.* 1-3, 1852-55. [1, n.s. 1-15, 1856-78. [10, 11, 15.

Cape Naturalist. 1, 1934+.

Cape of Good Hope. Royal Observatory. *Annals.* 1, 1880+. [2.

Chemical News and Journal of Industrial Science. 107-130, 1913-25. w. 117-118; 121-124. [142-144, 1930-32.

Chemical Society. *Annual Report of the Progress of Chemistry.* 1-26, 1904-30.

Chicago Academy of Sciences. *Bulletin.* 5, 1934+.

Earth Mover. [16-20, 1929-33.

Fan Memorial Institute of Biology, Peiping. *Annual Report.* 1, 1928/29+. *Bulletin.* 1, 1929+.

Field Museum of Natural History. *Botanical leaflet.* 17, 1934+. *Geological leafllet.* 13, 1933+.

K. Fysiografiska Sällskapet, Lund. *Forhandlingar.* 1, 1931+.

Hong Kong. Royal Observatory. *Extract of Meteorological Observations.* 1933+.

Indian Academy of Sciences. *Proceedings. A. and B.* 1, 1934+.

Instituto Biologico, Brazil. *Archivos.* 5, 1934+.

R. Istituto Superiore Agrario di Portici. *Annali.* 5, 1932+.

Iowa. University. *Studies in Natural History.* 6, 1911+. [6-9, 13.

Kuraschiki. Ohara Institut für Landwirtschaftliche Forschungen. *Berichte.* 2, 1921+.

Leipzig. Museum für Länderkunde. *Wissenschaftliche Veröffentlichungen.* 1, 1932+.

Lingnan Science Journal. 14, 1935+.

Louisiana. State University. *Extension Circular.* [1-155, 1915-33. *Louisiana Bulletin.* [54-260, 1898-1934; 261. 1935+. *Louisiana Circular.* 2, 1935+. w. 5, 6, 8. *Studies.* 2, 1931.

Maine. University. Agricultural Experiment Station. *Bulletin.* 364, 1933+. *Official Inspections.* 147-1933+.

Massachusetts Agricultural Experiment Station. *Bulletin.* 277. 1931+. *Bulletin. Control Series.* 59, 1931+

Mazoe. Citrus Experimental Station. *Annual Report.* 1933+.

Michigan University. Laboratory of Vertebrate Genetics. *Contributions.* 1, 1936+.

Musée Royal d'Histoire Naturelle de Belgique. *See* Brussels. Musée d'Histoire Naturelle de Belgique.

Naturwissenschaftlicher Verein für Schleswig-Holstein. *Schriften.* 20, 1933+.

K. Natuurhistorisch Museum van België. *See* Brussels. Musée Royal d'Histoire Naturelle de Belgique.

New Zealand Institute. *See* Royal Society of New Zealand.

Onderstepoort Journal of Veterinary Science and Animal Industry. *Formerly* Union Dept. of Agriculture. *Report of the Director of Veterinary Research.* 1, 1933+.

Osaka. Imperial University. Faculty of Science. *Collected Papers. Series B.* 1, 1933+. *Series C.* 1, 1933+.

Philippine Agriculturist. [1-19, 1911-31; 22, 1934+.

Physikalische Zeitschrift der Sowjetunion. 3, 1933+.

Porto. Universidade. Faculdade de Ciencias. *Anais.* 18, 1933+.

Porto Rico. University. *Journal of Agriculture.* 20, 1936+.

Preussische Geologische Landesanstalt. *Jahrbuch.* 1928+.

Revista Agricultura Comercio y Trabajo. [13-14, 1931-32.

Rhodesia Scientific Association. *Proceedings.* 1. 1899+.

Ricerca Scientifica. 7, 1934+.

Royal African Society. *Formerly* African Society. *Journal.* 31, 1932+.

Royal Canadian Institute, Toronto. *Proceedings. Formerly* Canadian Journal of Science. *Continued as* Transactions. 2-7, 1884-90 [2-4 n.s. Nos. 1-12, 1897-1904. w. 2. *Transactions. Formerly* the Proceedings. 1, 1889+.

Royal Physiographic Society, Lund. *See* K. Fysiografiska Sällskapet.

Royal Socitey of Arts. *Journal.* [57-81, 1908-33; 82, 1933+.

Royal Society of Canada. *Transactions.* Section 5. 27, 1933+.

Royal Society of New Zealand. *Formerly* New Zealand Institute. *Transactions and Proceedings.* 62, 1931+. [62.

Royal Society of South Africa. *Transactions.* 1, 1908/10+ [7.

Sciences. (Association Française pour l'Avancement des Sciences). *Formerly* Bulletin Mensuel. [1931-32; 1933+.

Scienza e Technica. (Societa Italiana per il progresso delle Scienze). 1, 1937+.

Societa Italiana per il progresso delle Scienze. *See also Scienza e Tecnica.*

Atti. Riun. 19-22, 1930-33; 25, 1937+.

Society of Mechanical Engineers, Japan. *Transactions* 1, 1935+.

South African Geographical Journal. 1, 1917+.

South African Sugar Journal. 8, 1924+. [8, 12-16.

South African Sugar Technologists' Association. *Proceedings.* 4-7, 1930-33; 10, 1936+.

South Australia. Public Library, Museum and Art Gallery. *Records of the South Australian Museum.* 5, 1933/36+.

K. Svenska Vetenskapsakademien. *Årsbok.* 1904+. *Handlingar.* 5, 1863+.

Taihoku Imperial University. Herbarium. *Contributions.* 28, 1933+.

Transvaal. Dept. of Agriculture. *Report of the Government Veterinary Bacteriologist. Continued as* Union. Dept. of Agriculture. *Report of the Director of Veterinary Research.* 1903/04-1909/10. w. 1905/06.

Union. Dept. of Agriculture. *Report of the Director of Veterinary Research. Formerly* Transvaal. Dept. of Agriculture. *Report of the Government Veterinary Bacteriologist. Continued as* the Onderstepoort Journal. 1-18, 1911-32.

Union. Fisheries and Marine Biological Survey. *Investigational Report.* 7, 1936+.

U.S. Bureau of Mines. *Annual Report,* 1936+. *Bulletin,* 385, 390+. *Economic Paper.* 18, 1936+. *Minerals Yearbook.* 1936+. *Minerals Yearbook. Statistical Appendix.* 1935+. *Technical Paper.* 533, 534, 547, 567+.

U.S. Dept. of Agriculture. *Agricultural Statistics.* 1936+.

U.S. Geological Survey. *Circular.* 1, 1933+.

Washington. University. *Publications in Anthropology.* 5, 1932+. *Publications in Biology.* 1, 1932+. *Publications in Geology.* 1, 1916+. [1, 2.

Western Australia. Geological Survey. *Bulletin.* 95, 1934.

P. FREER,
Honorary Librarian.

P.O. Box 1176, Johannesburg,
11th August, 1937.

TWENTY-SEVENTH AWARD OF THE SOUTH AFRICA MEDAL AND GRANT.

(Fund raised by members of he British Association in commemoration of their first visit to South Africa in 1906.)

After the conclusion of the Presidential Address in the hall of the S.W.A. Legislative Assembly, Windhoek, on Monday, 5th July, the President of the Association, Lt.-Col. C. Graham Botha, announced that the South Africa Medal and Grant had this year been awarded by the Council of the Association to Professor C. G. S. de Villiers, M.A., Ph.D., Professor of Zoology in the University of Stellenbosch.

The Medal and Grant were presented to the recipient by the Hon. Dr. Conradie, Administrator of the S.W.A. Territory, after the President had introduced the recipient in the following words:

Professor C. G. S. de Villiers was born in the Caledon District in 1894, matriculated in 1911 and took his B.A. degree at the Victoria College (now the University of Stellenbosch) in 1914 with Honours in Zoology.

In 1915 he was appointed at the Transvaal University College (now the University of Pretoria) as Assistant in the Department of Zoology, and in 1916 he took his M.A. degree at that Institution. In 1919 he proceeded to the University of Zurich (Switzerland), where he took his Ph.D. degree under Prof. Karl Hescheler. In 1923 he was appointed Professor of Zoology at the University of Stellenbosch, and in 1926 he was elected President of Section D of the South African Association for the Advancement of Science.

From 1930 to 1934 he was Dean of the Faculty of Science in the University of Stellenbosch. In 1934 he proceeded to Europe and carried out research work at the University of Rome and at several German Universities. In 1935 at the invitation of the Carnegie Corporation for International Peace he made a lecture tour of the Universities of New Mexico, California, Oregon and Harvard.

Professor de Villiers is a born researcher. His work is characterised by exactitude and thoroughness. He has made notable contri butions to knowledge in respect of Amphibian morphology, and for many years has been a source of inspiration to his students and colleagues.

Publications by Cornelius Gerhardus Stephanus de Villiers:—

1922. Neue Beobachtungen über den Bau und die Entwickelung des Brustschulterapparates bei den Anuren, insbondere die Bombinator. *Acta Zoologica*, Bd. 3, Seite 153.

1924. On the anatomy of the breast-shoulder apparatus of Xenopus. *Ann.Trans.Mus.*, Vol X, p. 197.

1925. On the development of the "epipubis" of Xenopus. *Ann. Trans.Mus.*, Vol XI, p. 129.

1925. Nuwe navorsinge oor die borsskouerapparaat van die Anura. *S.Afr.Jour.Sci.*, Vol. XXII, p. 226.

1926. Some aspects of the morphology and ontogeny of the skeletogenous strata. *S.Afr.Jour.Sci.*, Vol. XXIII, p. 63.

1929. The comparative anatomy of the breast-shoulder apparatus of the three Aglossal Anuran genera: Xenopus, Pipa and Hymenochirus. *Ann.Trans.Mus.*, Vol. XIII, p. 37.

1929. Some observations on the breeding habits of the Anura of the Stellenbosch Flats, in particular of Cacosternum capense and Bufo angusticeps. *Ann.Trans.Mus.*, Vol. XIII, p. 123.

1929. Some features of the early development of Breviceps. *Ann Trans.Mus.*, Vol. XIII, p 141.

1929. The development of a species of Arthroleptella from Jonkershoek, Stellenbosch. *S.Afr.Jour.Sci.*, Vol. XXVI, p. 481.

1930. On the cranial characters of the South African Brevicipitid Phrynomerus bifasciatus. *Quart.Jour.Mic.Sc.*, Vol. LXXIII, p. 667.

1930. Some aspects of Arnuran cranial osteology and osteogeny. *S.Afr. Jour.Sc.*, Vol. XXVII, p. 481.

1931. Uber den Schädelbau der Brevicipitidengattung Anhydrophryne (Hewitt). *Anat.Anz.*, Bd. 71, S. 331.

1931. The cranial characters of the Brevicipitid genus Cacosternum. (Boulenger). *Quart.Jour.Micr.Soc.*, Vol. LXXIV, p. 275.

1931. Further notes on the genus Cacosternum, including an account of the cranial anatomy of Cacosternum namaquense Werner. *S.Afr.Jour.Sci.*, Vol. XXVIII, p. 378.

1931. Uber den Schädelbau des Breviceps fuscus. *Anat.Anz.*, Bd. 72, Seite 164.

1931. Some features of the cranial anatomy of Hemisus marmoratus. *Anat.Anz.*, Bd. 71, Seite 305.

1932. Uber das Gehörskelett der äglossen Anuren. *Anat.Anz.*, Bd. 74, Seite 33.

1932. Die Skedelmorphologie van Hyperolius horstockii as voorbeeld van die Polypedatidae (met G. du Toit). *S.Afr.Jour.Sci.*, Vol. XXIX, p. 449.

1933. Breviceps and Probreviceps: comparison of the cranial osteology of two closely related Anuran genera. *Anat.Anz.*, Bd. 75, Seite 257.

1934. Die Schädelanatomie der Rhombophryne testudo Boettger in Bezug auf ihre Verandschaft mit den malagassischen Brevicipitiden. *Anat.Anz.*, Bd. 78, Seite 295.

1933. The "tail" of the American Toad Ascaphus. *Nature*, May 13, p. 692.

1934. On the morphology of the epipubis, the Nobelian bones and the phallic organ of Ascaphus Truei Stejneger. *Anat.Anz.*, Bd. 78, Seite 23.

1934. Some points in the anatomy of Microbatrachella capensis (Hewitt), and their bearing upon the question of phylogenetic neoteny. *S.Afr.Jour.Sci.*, Vol. XXXI, p. 406.

1934. Studies on the cranial anatomy of Ascaphus Truei Stejneger, the American "Liopelmid." *Bul.Mus.Comp.Zool.*, Harvard University, Vol. LXXVII, p. 3.

1935. Some aspects of the Amphibian suspensorium, with special reference to the paraquadrate and quadratomaxillary. *Anat. Anz.*, Bd. 81, Seite 225.

In Press. The cranial anatomy of the East African Gymnophiona Boulengerula boulengeri Tornier and Scolecomorphus ulugurensis Boulenger. *Anat.Anz.*

AWARDS OF THE SOUTH AFRICA MEDAL.

1908. *Grahamstown.*—Arnold Theiler, C.M.G., Dr.Med.Vet., Bacteriologist to the Transvaal Government, Pretoria.

1909. *Bloemfontein.*—Harry Bolus, D.Sc., F.L.S., of Sherwood, Kenilworth, Cape Division.

1910. *Cape Town.*—John Carruthers Beattie, D.Sc., F.R.S.E., Professor of Physics, South African College, Cape Town.

1911. *Bulawayo.*—Louis Péringuey, D.Sc., F.E.S., F.Z.S., Director of the South African Museum, Cape Town.

1912. *Port Elizabeth.*—Alexander William Roberts, D.Sc., F.R.A.S., F.R.S.E., of Lovedale Observatory, Cape Province.

1913. *Lourenço Marques.*—Arthur William Rogers, M.A., Sc.D., F.G.S., Assistant Director of the Union Geological Survey, Cape Town.

1914. *Kimberley.*—Rudolf Marloth, M.A., Ph.D., Cape Town.

1915. *Pretoria.*—Charles Pugsley Lounsbury, B.Sc., F.E.S., Chief of the Division of Entomology, Union Department of Agriculture, Pretoria.

1916. *Maritzburg.*—Thomas Robertson Sim, F.L.S., F.R.H.S., formerly Conservator of Forests for Natal.

1917. *Stellenbosch.*—John Dow Fisher Gilchrist, M.A., D.Sc., Ph.D., Professor of Zoology, South African College, Cape Town.

1918. *Johannesburg.*—Robert Thorburn Ayton Innes, F.R.S.E., F.R.A.S., Union Astronomer, Johannesburg.

1919. *Kingwilliamstown.*—James Moir, M.A., D.Sc., F.I.C., Government Mining Chemist, Johannesburg.

1920. *Bulawayo.*—Ernest Warren, D.Sc., Director of the Natal Museum and Professor of Zoology in Natal University College, Pietermaritzburg.

1921. *Durban.*—Sir Frederick Spencer Lister, Kt., M.R.C.S., L.R.C.P., Research Bacteriologist to the South African Institute for Medical Research, Johannesburg.

1922. *Lourenço Marques.*—Illtyd Buller Pole Evans, C.M.G., M.A., D.Sc., F.L.S., Chief of the Division of Botany and Plant Pathology, and Director of the Union Botanical Survey, Pretoria.

1925. *Oudtshoorn.*—Robert Burns Young, M.A., D.Sc., F.R.S.E., F.R.S.S.Af., F.G.S., Professor of Geology and Mineralogy in the University of the Witwatersrand, Johannesburg.

1927. *Salisbury.*—Annie Porter, D.Sc., F.R.S.S.Af., F.L.S., Parasitologist, S. Afr. Institute for Medical Research and Senior Lecturer in Parasitology, University of the Witwatersrand, Johannesburg.

1928 *Kimberley.*—Henry Hamilton Green, D.Sc., F.C.S., Professor of Biochemistry and Sub-Director of the Veterinary Research Laboratories, Onderstepoort, Pretoria.

1929. *Cape Town.*—Robert Broom, M.D., D.Sc., F.R.S., Douglas, C.P.

1930. *Caledon.*—Alexander Logie du Toit, B.A., D.Sc., F.G.S., Consulting Geologist to De Beers Consolidated Mines, Kimberley.

1931. *Grahamstown.*—Harold Benjamin Fantham, M.A., D.Sc., F.R.S.S.Af., F.Z.S., Professor of Zoology and Comparative Anatomy in the University of the Witwatersrand, Johannesburg.

1932. *Durban.*—John William Bews, M.A., D.Sc., Principal of and Professor of Botany in the Natal University College.

1933. *Barberton.*—Adrianus Pijper, M.D. (Leyden), Bacteriologist and Pathologist, Pretoria.

1934. *Port Elizabeth.*—Petrus Johannes du Toit, B.A. (C.G.H.), Ph.D. (Zurich), Dr. Med. Vet. (Berlin), D.Sc. (Stellenbosch, *honoris causa*), Director of Veterinary Services of the Union.

1935. *Paarl.*—Edwin Percy Phillips, M.A. (C.G.H.), D.Sc. (C.G.H.), Principal Botanist, Division of Plant Industry, Department of Agriculture.

1936. *Johannesburg.*—John Hewitt, B.A. (Cantab.), D.Sc. (*hon. causa*, S. Africa) Director of the Albany Museum, Grahamstown.

1937. *Windhoek.*—Cornelius Gerhardus Stephanus de Villiers, M.A., Ph.D., Professor of Zoology in the University of Stellenbosch.

AWARDS OF THE BRITISH ASSOCIATION MEDAL AND GRANT.

(Founded by the British Association in Commemoration of its Second Visit to South Africa in 1929.)

1932. *Durban.*—Miss Nellie Freebairn Paterson, M.Sc., Ph., Lecturer in Zoology, University of the Witwatersrand, Johannesburg, for her paper on "The Embryology of *Euryope terminalis.*" (See this Journal, Vol. XXVIII, 1931, pp. 344-371, and Vol. XXIX, 1932, pp. 414-448.)

1933. *Barberton.*—Miss Tikvah Alper, M.A., for her paper on "Wilson-chamber Experiments on δ-rays, and the Ranges of Low-speed Electrons." (See this Journal, Vol. XXIX, 1932, pp. 248-261.)

1935. *Paarl.*—Miss Margaret Orford, B.Sc., for her paper on "The Pelvis of the Bush Race." (See this Journal, Vol. XXXI, pp. 586-610.)

1936. *Windhoek.*—Oliver West, M.Sc., for his paper on "An Investigation of the Methods of Botanical Analysis of Pasture." (See this Journal, Vol. XXXIII, 1936, pp. 501-559.)

Windhoek.—Ronald Elsdon-Dew, M.D., Ch.B., for his paper on "The Application of Blood-grouping to South African Ethnology." (See this Journal, Vol. XXXIII, 1936, pp. 976-992.)

LIST OF PAPERS READ AT SECTIONAL MEETINGS, 1937.

MONDAY, 5 JULY.

PRESIDENTIAL ADDRESS (to all Sections) on "The Science of Archives in South Africa," LT.-COL. C. GRAHAM BOTHA, V.D., M.A.

SECTION A.—ASTRONOMY, MATHEMATICS, PHYSICS, METEOROLOGY, GEODESY, SURVEYING, ENGINEERING, ARCHITECTURE AND IRRIGATION.

MONDAY, 5 JULY.

1. Presidential Address on "The History of Land Survey in South West Africa," A. C. PARRY, Surveyor-General, South West Africa.
2. "The Pulsation Variables: A Statistical and Analytical Study of the Phenomena of Cepheid and Long Period Stellar Variability," DR. A. E. H. BLEKSLEY.
3. "Neue Geophysikalische Beziehungen der Meteore," DR. C. HOFFMEISTER.

SECTION B.—CHEMISTRY, GEOLOGY, METALLURGY, MINERALOGY AND GEOGRAPHY.

TUESDAY, 6 JULY.

1. Presidential Address on "Some Geographical Aspects of the Peopling of Africa," PROFESSOR J. H. WELLINGTON.
2. "A Study of the Chert of the Dolomite Series of the Transvaal System," V. L. BOSAZZA.
3. "Industrial Research: The Need for Co-operation," DR. V. BOSMAN.
4. "pH Control in South African Tanneries," S. G. SHUTTLEWORTH.

SECTION C.—BOTANY, BACTERIOLOGY, AGRICULTURE AND FORESTRY.

TUESDAY, 6 JULY.

1. Presidential Address on "Transpiration and Water Supply of South African Plants," DR. M. HENRICI.

MONDAY, 5 JULY.

2. "Phytophthora Wilt in Carnation Plants," EVARDINA E. WIJERS.
3. "*Atalaya Capensis:* A New Generic Record for South Africa," DR. R. A. DYER.
4. "Sward Density and Weed Invasion of Woolly Finger (Pretoria Small) Pasture under Different Grazing Treatments," S. NOLA SCHOEMAN.
5. "A Contrbiution to the Ecology of the High Veld Flora," P. E. GLOVER.
6. "The Plant Communities and Other Points of Interest of the Witwatersrand and Magaliesberg," R. ROSE-INNES.

TUESDAY, 6 JULY.

7. "An Improved Method in the Study of Root Bisects," N. G. VAN BREDA.
8. "A Method of Charting Karoo Vegetation," N. G. VAN BREDA.
9. "Preliminary Studies on the Root System of *Galenia Africana* in the Worcester Veld," J. D. SCOTT and N. G. VAN BREDA.
10. "The Productivity of Fertilized Natural Highveld Pastures," T. D. HALL, D. MEREDITH and S. M. MURRAY.
11. "Leaf Scald of Barley in South Africa," PROFESSOR NOEL J. G. SMITH.
12. "Poikilohydre Pflanzen in S.W. Afrika," DR. G. BOSS.

SECTION D.—ZOOLOGY, EUGENICS, PHYSIOLOGY, HYGIENE AND SANITARY SCIENCE.

THURSDAY, 8 JULY.

1. Presidential Address on "The Old Surviving Types of Mammals found in the Union," DR. AUSTIN ROBERTS.

TUESDAY, 6 JULY.

2. "The Influence of Limestone Flour and Bone Meal Feeding on Egg-shell Formation," A. M. GERICKE, M. J. VAN DER SPUY and U. W. SCHMIDT.
3. "Public Health and Medical Services in South-West Africa," DR. F. C. S. HINSBEECK.

THURSDAY, 8 JULY.

4. "Infra-red and Ultra-violet Radiation in Relation to Animals and Plants," CLYDE FERGUSON.

SECTION E.—ANTHROPOLOGY. ETHNOLOGY, ARCHAEOLOGY, PHILOLOGY AND NATIVE SOCIOLOGY.

THURSDAY, 8 JULY.

1. Presidential Address on "Man in Africa in the Light of Recent Discoveries," DR. A. GALLOWAY.

MONDAY, 5 JULY.

2. "The Hyoid Bone of Negro and Pre-Negro South African Races," G. W. H. SCHEPERS.
3. "A Contribution to the Physical Anthropology of the Ovambo," DR. A. GALLOWAY.
4. "The Status of the Bushman as Revealed by a Study of Endocranial Casts," L. H. WELLS.
5. "Prehistoric Rock Paintings in Northern Rhodesia," PROFESSOR C. VAN RIET LOWE.
6. "A Note on Some Unusual Beads from Southern Rhodesia," G. F. BERRY.

TUESDAY, 6 JULY.

*7. "Finger Mutilation in the Bushmen," PROFESSOR M. R. DRENNAN.
8. "Die Buschmänner Südwest Afrikas and Ihre Weltanschauung," DR. H. VEDDER.
9. "Relationship between the Nation and its Language," HANS BETZLER.

SECTION F.—PSYCHOLOGY, EDUCATION, NATIVE EDUCATION, SOCIOLOGY, ECONOMICS AND HISTORY.

THURSDAY, 8 JULY.

1. Presidential Address on "The Evolution of Psychiatry," DR. W. RUSSELL.

TUESDAY, 6 JULY.

2. "The Application of Word-Association Tests to Certain Groups of South African Subjects," A. S. J. COETSEE.
3. "The Scientific Basis of Physical Education," DR. E. JOKL.
4. "A Social Study of Law," ADVOCATE I. GOLDBLATT.

* This paper has been published in *Bantu Studies*, September, 1937.

The price of this Journal to the general public is as marked on the front page. Every member of the Association is supplied with one copy free, and may obtain extra copies at half-price. Applications for copies should be addressed to the Assistant General Secretary, P.O. Box 6894, Johannesburg.

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Communications for the Editor should be addressed to P.O. Box 1176, Johannesburg.

PAPERS for publication should be condensed and limited as far as possible to the description or discussion of new facts, new observations, or new ideas. They should be typewritten and carefully corrected.

ILLUSTRATIONS (other than photographs and half-tones) accompanying papers intended for publication in the Journal must be supplied by the authors, carefully drawn about **twice the size** of the finished block, on smooth white Bristol board, in **India ink,** so as to admit of the blocks being prepared directly from the drawings. Any lettering on these drawings should be of such a size that it will be clearly legible when reduced. For graphs, squared paper ruled in pale blue **only** should be used, otherwise the ruled squares appear black in the photographic reproduction. The size of the printing area of a page of the Association's Journal, including space for legends, is 7in. × 4in.

The attention of authors is also directed to the first paragraph of By-law 6, requiring them to submit abstracts of their papers, together with the original papers, to the Recorder of their Section **at least a fortnight** before the beginning of the Annual Session.

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SUBSCRIPTIONS.—Subscriptions of £1 10s. for the year ending 30th June, 1938, are now due. Members are requested to remit this amount as soon as possible to the Assistant General Secretary, P.O. Box 6894, Johannesburg. Unless members pay the amount due at an early date, great inconvenience and unnecessary expense is caused, as it is very difficult to determine what number of copies of the Journal will be required. The Council therefore appeals to every member for support and co-operation, and asks that outstanding subscriptions be paid without delay. **The Journal will be sent only to those whose arrear subscriptions are paid.**

Cheques, etc., should be crossed and made payable to the **Association, not to the Secretaries or Treasurer individually.** Sixpence should be added to country cheques for exchange.

HEADQUARTERS.—The offices of the Association are located in the building of the Associated Scientific and Technical Societies of South Africa, Kelvin House, corner of Hollard and Marshall Streets, Johannesburg. The postal address of the Association is "P.O. Box 6894, Johannesburg," telegraphic address, "Science, Johannesburg," and telephone number 33-5710.

Johannesburg, November, 1937.

SOUTH AFRICAN JOURNAL OF SCIENCE, *Vol. XXXIV, pp. 1-17, November, 1937.*

THE SCIENCE OF ARCHIVES IN SOUTH AFRICA.

BY

Lt.-Col. C. GRAHAM BOTHA,
Chief Archivist of the Union,
President,

Presidential Address delivered 5 July, 1937.

The first duty I have to perform in presenting my Presidential Address is to tender my sincere thanks to those who have elected me to the high office of President. I am fully conscious of the honour bestowed upon me. Many of my predecessors have been outstanding scientists whose names will live long in the history of science of our country. Among them have been a few who belong to that silent band of my fellow workers known as Civil Servants.

Another duty I feel honoured to perform is to tender, on behalf of our Association, our cordial and hearty thanks to the people of Windhoek for providing a meeting place and for the open hospitality and splendid welcome given to-day. This is the first occasion our Association has met at Windhoek, and, for that matter, in South-West Africa. This visit is unique and should be recorded as an important milestone in the Association's history.

The decision to meet here is only carrying out a practice of the Association for many years, namely, to meet not only at different centres within the Union, but also to have meetings beyond its boundaries. It is a wise practice and fully bears out the saying, "Science knows no barriers," and in this instance no territorial boundaries. These annual meetings serve several useful purposes. They bring science workers together, who may learn from each other by discussion or papers read. They bring these workers in contact with the people of the centre visited. There can be no doubt that at such meetings a powerful stimulus from each other is derived. Many members obtain suggestions for new lines of research, which may result in future visits to a centre when time and opportunity permit a fuller study.

This meeting in particular should fulfil the purposes just enunciated as well as carry out the object of the Association, which is to promote the intercourse of societies and individuals interested in science in different parts of South Africa. General Smuts in his Presidential Address at Oudtshoorn in 1925 amplified this when he remarked that the aim was to promote a

scientific spirit and the love of scientific research and development among the people of South Africa. The Association, he added, welcomed and invited as members all who sympathised with its aims, whether they were scientific experts or not. While it may be true that we look to the scientist for the advancement or progress of science, yet the fruition of his work depends in some measure on the sympathy and enthusiasm of that band of ordinary workers who may not be experts. Our aim should be to maintain contact between the scientific worker and the nation in general. This would surely help us to realise the ideal set forth in the title of our Association, viz., the Advancement of Science.

This is the first occasion that an Archivist has been elected as President of the Association, and, therefore, I am all the more conscious of the honour conferred upon me. The President is not restricted in the choice of the subject for his Presidential Address. but as a matter of general practice confines himself to giving a review of the work done in the science with which he is most acquainted. For this reason I have taken my work as the theme of this address and propose to speak on the Science of Archives in South Africa, a subject very different to that chosen by my predecessors, but nevertheless of importance to all to-day.

Someone may question the claim of the study of Archives as a science. What is science? In giving an answer we will find a variety of definitions. We will find ourselves in a hurly-burly and emerge finding the conflict was a battle of words and that a preliminary definition might have obviated the greater part of the conflict. Professor F. J. C. Hearnshaw writes that science can be quite accurately and adequately, as well as quite simply, defined as "systematised, organised, formulated knowledge." Professor T. H. Huxley understands science to be all knowledge that rests upon evidence and reasoning, and Professor Karl Pearson shows that the classification of facts, the recognition of their sequence and relative significance, is the function of science. If in practice some subjects have to be excluded from the ranks of the sciences, their exclusion is due solely to the fact that, when exposed to those tests of a science—search for truth, accumulation of fact, critical judgment, elimination of prejudice—their content vanishes away.

To-day the study of work connected with Archives has been recognised in European countries as a science.

The recognition of the Science of Archives appears to be well founded, not only because it can be described as "systematised, organised, formulated knowledge," but also when the relation between its methods and those of other sciences is taken into consideration. The Entomologist, for instance, collects, arranges, classifies and describes his collection. The Archivist performs similar functions with the documents he collects. He arranges, classifies, describes and indexes his collection. The

Palaeontologist reconstructs the appearance of animals that have lived in the distant past, and in this respect closely resembles the Archivist in whose work reconstruction also plays an important part. The Archivisit not only reconstructs the retroacts of institutions as a whole, but often has to bring together the *membra disjecta* of individual documents. In this again he resembles the Historian who also reconstructs, or rather brings about a resurrection of the past. It is unnecessary to dwell on further points of resemblance between the science of Archives and History, as it is obvious that the Archivist is instrumental in supplying the Historian with his most important data.

The day of keeping Archives in a haphazard way has gone. The work of sorting, arranging and classifying has been reduced to a science. Most countries have adopted a generally recognised system of rules for the guidance of the Archivist. The importance of proper archival administration has led to the science of archive economy. The primary elements of this science are (a) the bringing together under one administiation of all archives not in current use, (b) the efficient and scientific classification and general administration of documents so centialised, and (c) the custody of the archives under competent officials. The activities of the archives administration and science are identical. For what is the basis of the historical science? In the ethical sense it is freedom and truth, in the technical sense order. This scientific character is not the prerogative of the historian alone, but the common property of all, especially the Archivist. The work of the Archivist is scientific because his method is such as well as his goal.

The old conception of what archives are and their administration still persists with some persons who have not kept pace with their development and organisation. The old idea was that archives represented a collection of dusty and musty records kept in a haphazard manner in the basement or attic of a building, and were used occasionally by some crank trying to probe into the past. The prevalent conception of an archives establishment was that of a warehouse for the storage of records. The complaint of the Archivist against the general ignorance of the public concerning the work in a archives is not only of this century. The grievance is not only against the average person, but against those of learning. Many do not appreciate the value to the nation of the treasure house of information in the archives which contain valuable material for the historian, the economist, the socialist, the student of political science, the legal investigator, and for the science of administration. They give us a vivid picture of early times, events, conditions of the people and personalities. It is only when we have a closer knowledge of these authentic authorities that the past begins to take form and live. We are in danger to-day of praising ourselves on account of great discoveries in science. But we should use caution in this self-praise, for when we enquire into the past we will find

that our discoveries are but the result of circumstances and events based on the past. The more people know of the history of their development and the value of their strength and what has brought them to that state, so much the more will they be spurred on to other obligations. They will never understand their political, scientific and spiritual development without an understanding of the past in which they are rooted. As it is tersely expressed in Dutch: "Uit het verleden leert men het heden kennen." To gain this understanding recourse must be had to the records of the past.

There was a time when history was not recorded, but the thoughts and actions of a people were handed down orally. The story was told and retold as it was remembered, resulting in gaps filled in according to the narrator's power or imagination or purpose. For the want of documents long periods in the history of a people would remain unknown for ever. There is no substitute for documents: no documents, no history.

When man acquired the art of writing thoughts and actions were recorded, the records or documents becoming the traces of past events. The records so created became, in course of time, the first and most important tools of the historian's craft. History has become very largely dependent upon documents. They are the source of historical knowledge and give us information on living beings and material objects, actions and words of men, motives and conceptions. The documents acquaint us of people, their physical condition, their arts and industries. What was seen or heard of a people or of events was recorded. History may be made by action and thought and the written word is directly informative and absolute in its appeal. History enquires into all existing relics and records of the past as seem likely to assist in the explanation and elucidation of the present. The course of history largely depends on contemporary record and the subsequent collation of documents. Following writing came the art of printing which helped to promote widespread dissemination of knowledge.

With the advance of science, especially since the beginning of the 20th century, we find new methods of recording the thoughts and actions of men, namely the motion picture and the recording of sound. These are an aid to read man's thoughts and actions in words, see his thoughts in picture and hear his thoughts and emotions as well. Here begins a new record of history.

We are primarily concerned here with the written record. Motion picture and sound record come within a period of more recent development and their full value to future generations is a matter of consideration. When speaking of archives in this address I refer to national archives, which are the documents, papers and other records made or received in the transaction of public business by the officials of a national government and filed

for preservation by or for the officials concerned. The word archives also refers to the institution that has been created to have custody of the national archives in the other sense. In early days when European countries began to send their archives to a central depot for safe custory, little consideration was given to the question of sorting, arrangement and classification, and to the problem of accessibility and administration. Gradually steps were taken to bring order out of chaos and, after many unsuccessful experiments, documents were arranged and classified on a scientific basis. There was to be no confusion with the classification of a library as had been the idea in former years. There was not to be a purely chronological or purely alphabetical arrangement. What was to be aimed at was a thorough knowledge of the history and functions of the office, the records of which were arranged. The collection was to be classified according to their origin and was to reflect the process by which it came into existence. In short, for more than a century European countries have given serious thought to the preservation and arrangement of their national archives.

The matter did not reach perfection all at once. It took time and gradually a system of keping archives was evolved, which is recognised to-day by most countries. This system recognises that the only sound principle for the classification of archives is the " principe de provenance " with " respect des fonds " as the French call it, or " het herkomstbeginsel," as the Dutch term it, or " die Provenienz seiner Bestande," as defined by the Germans. This " principe de provenance " is the system of arranging public archives whereby every document is traced to the governmental body, administrative office, or institution by which it was issued or received, and to the files to which it last belonged, when these files were still in the process of natural accretion.

But what of the Archivist to whom is entrusted a most priceless heritage of the nation? Much responsibility rests upon him in preserving this heritage and he must be trained to undertake the scientific work allotted to him. The importance of a nation's archives has been recognised by most governments of the world, and special provision made for their preservation. The duties of the Archivist are primary and secondary. His primary duty is to take adequate precautions for the safeguarding and custody of his archives and against those destructive agencies to which records may be subjected. He is responsible for the internal archival economy. The *conditio sine qua non* for their preservation is the protection in fire-proof, well ventilated and dry rooms. His second duty is to see to their efficient and scientific classification and prepare lists, inventories and catalogues for their easy accessibility by all who wish to consult them.

Recognising the nature of this scientific work, many countries have established archives schools to prepare students for

archival work. Where no such school exists special courses are provided by the Universities. It is essential to have trained men for this work which can only be entrusted to those who show proof of their qualification. Some countries, such as France, Germany, Holland and Belgium demand several years training of a high standard. An archives office is not merely an administrative one, but is also a scientific institution. In Europe archivism is a profession.

My remarks so far indicate that national archives have a value to the country. Archives have been rightly called the "recorded image of the past." They constitute a fundamental source of historical information and reflect various aspects of the life of the people, and are a means of ascertaining the truth with respect to the history of the country. Their study and arrangement is a science.

Let us now direct our attention to South Africa in regard to the archives and their administration. Prior to the date of Union the Cape Province gave attention to this subject more than half a century ago, and the Transvaal since about 1902. In 1919 the Union Government took the first serious step in co-ordinating the archives of the four provinces.

The administration of Union and Provincial archives was centralised in a Chief Archivist and by legislation of 1922 Union and Provincial archives depôts were created, the former at the seat of Government of the Union and the latter at the seat of the provincial administration. The centres thus are in Capetown, Pretoria, Pietermaritzburg and Bloemfontein, each in charge of an Archivist and the whole administration centralised in the Chief Archivist. This system secures uniformity of administration, arrangement, classification, inventorying, methods of preservation and general care. It has resulted in straightforward administrative efficiency and experience has taught that it is the only satisfactory method. Experts in archive economy the world over endorse this system.

The archives department is a young branch of the public service of the Union of South Africa. Its advance, unspectacular but steady during the last decade or so, was marked by a persistent claim to recognition as an integral part of the Government machinery and the necessity for its personnel to be men with a certain standard of education and an aptitude for the work.

An archives depôt is not static and must increase in quantity and quality as the years pass. But this can only happen if it is given the proper and right kind of nourishment. The department was conceived no doubt as a branch of the service with great possibilities. Its growth was slow at first and to some extent stunted because it had to overcome many prejudices. When it was born people began to enquire what were archives and what functions did the department perform. It

was something foreign to many people. The erroneous ideas even to-day held by some people as to the real functions of an archives are amusing but nevertheless disturbing as indicating the ignorance which persists.

When it was given a place in the government machinery by legislation, it had to live down the prevalent conception that it was a warehouse for the storage of records with someone in charge to keep them from deterioration and permit their consultation when necessary. It had to have a proper home and the right kind of vitamins in its food to allow it to develop. But this stripling of a department struggled on, facing all the obstacles which beset it. It hoped to outgrow these and pass on to manhood when it could claim a status along with other departments and with similar institutions of older countries.

Let me lay aside this figure of speech, but at the same time remark that it reflects briefly the story of the birth, growth and development of the archives department of South Africa. This country had the advantage of studying the system of similar institutions of older and more experienced countries. It avoided the pitfalls made by them in the past and took the best from each country and adapted this to suit the conditions in South Africa. Other sections of the British Commonwealth of Nations subsequently gave attention to the organisation of their national records, such as the Commonwealth of Australia and the Dominion of New Zealand. The most recent recruit is the Colony of Southern Rhodesia, which created an archives department by legislation a few years ago. From the three countries enquiries came to South Africa regarding the system of archives keeping in this country.

Within the last ten years the archives at Capetown, Pietermaritzburg and Bloemfontein have been transferred to their own buildings with up-to-date equipment and protective devices at a cost of many tens of thousands of pounds. Steps are being taken to provide a separate building at Pretoria, which will house the Provincial archives and contain the records of the Union Government when old enough for transfer as laid down by law.

To illustrate the growth of this branch of the service the following figures show the increase of the personnel and salary expenditure during the last eighteen years.

Year.	Personnel.	Expenditure.
1919	5	£2,805
1924	8	£2,863
1929	18	£4,520
1934	30	£7,644
1937	42	£11,000

The number of researchers and visitors and volumes consulted during the last five years indicates a steady and encouraging increase.

The system adopted for the arrangement and classification of the archives in South Africa is that recognised in Europe and previously referred to as "the principe de provenance" with "respect des fonds," "Het Herkomstbeginsel" or "die Provenienz seiner Bestande." Experience has shown that this system is the only sound one. After the records have been arranged and classified, lists, inventories and catalogues are prepared to assist the staff and the historian in knowing what archives exist in the repository, the quantity and quality.

I have already touched briefly on the duties of the Archivist. We will look at this aspect in a little more detail as far as South Africa is concerned. His primary duty relates to the physical defence of his archives, which involves questions of a proper repository, accommodation for the researcher, economy of space, shelves, handling and damage, theft, misplacements and repair of his archives. It also relates to the moral defence of his archives which refers to their reception and arrangement. In the duty of arrangement he must study the administrations concerned, their history and organisation and divide them into classes and sub-divisions of these. He will only understand his archives if he has a knowledge of the administration which produced them. In the archives themselves he will often see the history and development of that administration. It is in this work that the Archivist will bring into play his scientific knowledge as laid down for the arrangement of archives.

His secondary duty relates to the special requirements of the student. He has to prepare guides, lists, inventories and catalogues of his archives. For the student living a distance from the depôt and unable to consult the documents, full transcripts must be prepared and published under an editor.

But there are many more matters which require attention. He has to consider seriously the destruction of certain ephemeral archives which are already in his custody. The Archivist, as a rule, has a great objection to any destruction, but an accumulation of valueless material imperils accommodation, increases the work of the staff as well as complicates the work of the student by reason of its bulk. The Archivist, in his task of destruction, is, however, guided by statutory rules which provide machinery to destroy but with safeguards in the interest of the State and the historian. By the same statutory measures the Archivist in South Africa has another duty put upon him. He is concerned with the archive-maker of the present and the "weeding out" of types of his records. The growing mass of departmental records of to-day would be a source of anxiety to the Archivist of the future if no steps were taken to cut this down before such records are ready for transfer to his custody. In order then to prevent this accumulation at all the law provides for a certain amount of destruction under certain safeguards. The authority to destroy emanates from the archives which acts in conjunction with the department whose records are under consideration. This

" weeding out " process is a great assistance to the department concerned by giving more storage space for its records and helping the Archivist to reduce his work of destruction when the collection is finally transferred to his care. In the process of destruction the Archivist has to consider not only the historian of to-day but also of the future. He must have a clear conception of the principles of historical science. Again statutory measures impose upon him the task of receiving into his care and custody accretions of documents from departments when such are old enough for transfer. The law of South Africa makes it compulsory upon State departments to send these to the archives.

The advancement of science has added another source of recording history, namely motion pictures which give mobility to recorded knowledge. The pioneers who agitated for a proper system of archives keeping and for adequate housing of our records did not at first contemplate the preservation of motion pictures. The introduction of the " movies " was looked upon as a medium of entertainment and used at first to amuse. But there were people who saw in the " movies " a medium of instruction and a record for future generations. Gradually the prejudice against the preservation of certain types of motion picture pertaining to and illustrative of historical activities of a country which would be of historical value was overcome. Governments began to look upon them as archives and to establish a separate branch of the establishment for their preservation. South Africa fell into line with this and in 1933 created a film archives under the archives department.

This has meant new archival problems for the Archivist, for he has to provide adequate means to reduce fire hazards and to devise means to prolong the life of the film material so that it would keep like other records. It is here that the scientist must come to the aid of the archives. There are many matters connected with the preservation of film archives which have to be taken into consideration. Questions such as the following have to be studied. Which gives greater stability, the acetate or the nitrate film; what are the effects of humidity and variation of temperature upon them; the effects of residual hypo or other active materials in the film upon the stability of the film base of image, the necessary restoratives in the storage containers to prevent loss of flexibility—should they be stored in hermetically sealed or vented containers—the effects of light and heat upon the film during projection?

Closely allied to the problem of preserving motion films there is another one which has to be carefully considered. How long will photographic films of documents copied last? The Archivist has to study other problems which have been introduced through the progress of science. What is to be the place of micro-photography in archival practice? Does micro-photography open the way to securing films of documents at a reduced cost and

should the camera be utilised to duplicate large amounts of documentary material? What use could be made of ultra-violet and infra-red rays in manuscript work? The ultra-violet rays have been introduced into archival work in South Africa. The potentialities of the use of these rays in the archives will be known as time passes. So it will be gathered that the Archivist must keep abreast with the times if he wishes to carry out his work scientifically.

He owes much to the advancement of science and in some of his problems depends upon the aid of the scientist. In the preservation of motion and of photographic films he brings in the aid of science, as well as in the question of inks and paper in as far as they can be preserved for posterity. The Archivist in carrying out his duties therefore relies upon other branches of science as well as the science of archives.

A more detailed account would reveal many other duties, but I have said enough to illustrate the general range of his activities. Although the administration of the four archives depôts in South Africa is centralised in one person—the Chief Archivist—resulting in general uniformity of arrangement, classification, inventorying, methods of preservation and general care, there are common as well as exceptional problems to each Archivist. To make for greater uniformity and in order to solve the exceptional problems, a conference of South African archivists is held periodically at one or other centre. This brings each one in touch with the other, and enables a thorough discussion of, and to an extent the solving of, difficulties. This serves as a clearing house for ideas and suggestions, and from this archival pooling specific problems disappear, archives economy is enriched and the science of archives advanced.

The foregoing will have indicated, I trust, that the Government of the Union of South Africa has awakened to the realisation of the value of its national archives and has taken steps to preserve them. All enlightened nations admit that a State owes a duty to its history, and that its public records should become accessible. Archival care and accessibility should be the ideal of every country. The building up and development of an archives institution calls for up to date methods and a study of what is being done in other countries. Keeping pace with the times, looking ahead to future generations are essential to its development on a sound basis.

Let me summarise briefly my statements so far. The study and work connected with archives have been recognised as a science; a scientific system of keeping archives has been evolved; archives constitute a fundamental source of historical information; South Africa has followed the lead of older countries of Europe in preserving her national archives on the same scientific basis; in the early growth of the archives department prejudices and misconceptions of what archives were and what

the administration stood for had to be overcome; its growth and development have been slow but sure; the duties of the Archivist are multifarious; the advancement of science has brought new means of recording history and preserving records which have added to the duties and problems of the Archivist who relies upon other branches of science as well as the science of archives; it is necessary to keep pace with the progress of the times to have an archives institution built up and developed on sound up to date lines.

I have tried to give a bird's eye view of the science of archives, and what duties devolve upon the administration. I will now endeavour to show whether archives can elucidate any particular phase of the past. History, I have pointed out, is dependent upon records and enquires into such records as seem likely to assist in the explanation and elucidation of the present. History has become largely dependent upon documents: no documents, no history.

If we search the archives many examples could be given showing that present-day problems have their counterpart in the past. One illustration, however, will have to suffice. I will take the question of our national roads, the creation of a national road fund and the constitution of a National Road Board in 1935, and look at the same question of roads and road administration as it appears from the records of the last two centuries. The creation of the fund and the constitution of the Board were matters spoken of for many years. It was the response to one of the country's great needs regarding national development, and may bring in its wake cheap transportation which will promote the country's material prosperity and give ease of intercourse which will be an important element in the building up of national unity. Those who have followed the press comments of the doings of the National Road Board since its first meeting two years ago and have read its first report, will appreciate that it has had to face many problems and difficulties. Those who have studied the archives of a century or more ago will come to the conclusion that our forefathers had many similar problems and difficulties to overcome.

The National Road Board has realised that it has to meet certain opposition here and there. Experience has shown that decisions to deviate national roads from certain old routes have brought opposition There is frequently considerable diversity of local opinion regarding any particular route and the Board has to make a closer examination of proposals for national roads. There are national roads which pass through municipal areas. Gaps in the national road system made by municipal roads and streets will be a problem. Is the old main route passing towns and villages to be deviated by the national road? What are the merits of steel-tyred and pneumatic-tyred vehicles and what type of road is to be constructed to meet the requirements of present-day traffic? There may be one section of the com-

munity who will consider that enough is not spent on it whilst another will complain that it does not get a fair return for its contribution to the Treasury. These problems were in some respects not unknown to the pioneers of roadmaking a century ago.

Our archives disclose the story of South Africa's early road system and administration from the seventeenth century. During the seventeenth and eighteenth centuries the making and maintenance of the highway was left in the hands of the local authorities, the Burgher Senate for the Cape District and the Board of Landdrost and Heemraden for the country areas. Enforced labour was used and every year the burghers or their substitutes were obliged to appear on a section of road with pick and shovel, wagon and oxen or horses. Everyone had to give his service gratuitiously whether he was rich or poor, a landed proprietor or not. The Board appointed road surveyors or overseers chosen from among the people, gave them a list of the people to be called up in their area, and specified the time to be taken on each section of road, which varied from a few days to fourteen days. On completion of the work the overseer handed in his road roll, noting those present and the absentees. Two Commissioners from the Board then inspected the road. Delinquents were dealt with by the Board and fined or reprimanded and warned to obey future orders. Overseers neglectful of their duties were fined. The road work consisted of removing boulders, filling up ruts and depressions. The road at the best of times was barely trafficable and received indifferent repair between each period of " mending." The traffic and rains soon destroyed the soft material used in filling the holes.

But it was not all enforced labour by which roads were constructed and repaired. The communal spirit was not wanting, and there are instances where this was undertaken by the voluntary action of a group of public-spirited inhabitants. They appointed their own overseers and contributed the necessary labour, transport and tools. On the other hand certain mountain passes were kept in order by a contractor and the users paid a tax or voluntary contribution into the district treasury. Where users of one district used a road through another district, a contribution was made from the treasury of the former to the latter district.

The records refer with some regularity to the notices to overseers, to the presentment of their rolls, to calling out of the inhabitants, to penalties imposed on defaulters—whether overseers or labourers. Yet they refer frequently to the bad condition of the roads.

It could hardly be expected that there would be good roads in a country covering many thousands of square miles, sparsely populated and settled areas separated from each other and from the capital by rugged mountains with unbridged rivers, with

trade restrictions, with few markets, with a government at times unsympathetic to the interests of the people, with a system of road administration in the hands of each district dependent upon free labour, we can take it for granted that the road work was not always willingly performed nor without grumbling at times. There was a certain amount of loitering and only a few days' work was done out of the several days the road party was at work. We may also assume that the overseer or the most notable inhabitant living near the section under repair would want that portion of the road mended which served them best. It would be safe to assume that there was remissness both by overseers and suppliers of labour. Overseers, though regularly obliged to call out their neighbours, or even relatives, must have overlooked absentees at times as they would not wish to quarrel or become unpopular with them. How the overseers went to work must be left to the imagination. They were appointed annually, were unpaid, and for the most part had little idea of road work.

The beginning of the nineteenth century saw no change in the road system or improvement of the highways. The Government, however, was awakening to the necessity of good roads and what they meant for the comfort and convenience of the traveller, to the use of lighter vehicles with fewer draught animals, to better internal communication and to the improvement of inland trade and to the social welfare of the people.

The first big undertaking was the construction of a mountain pass at French Hoek, opened in 1825. But the advantages anticipated were not realised and the people still preferred to take the old route to the east over Hottentots Holland Kloof to which the Government next gave attention. A pass was opened in 1830 and named Sir Lowry Pass. It was the key to the whole of the Colony and lay upon the Great Eastern Route. Its construction made the community appreciate the benefits to be derived from new roads and the necessity of having proper channels of communication so as to give the farmer a quick and safe way of bringing his produce to the principal markets. It did more, for the public began a campaign to have good roads and were supported by the press. Meetings were held, petitions were drawn up and the demand for better roads became more insistent and urgent.

The thirties of the nineteenth century saw a gradual development in agricultural and pastoral production in the Colony, such as wool, skins, hides, grain, wine, etc., and there was an increase in foreign trade. There was an urgent need for land communication between the coastal areas and the interior to open up markets and give an impetus to export. The internal trade had to be carried on by the slow moving ox-wagon, which had to travel over dangerous and rough roads, making it an expensive and unwieldly business. In the absence of navigable rivers and railways, it became all the more necessary to have

good roads if this economic development was to advance and the prosperity of the country improved in every direction.

Many of the mountain barriers over which the main line of road crossed were almost impassable. To traverse them meant loss of property, damage to vehicles, toil and cruelty to draught animals. The bridgeless rivers when in flood caused loss of life, delayed passengers, the mail and justice when judges went on circuit. All these factors were brought home more and more to the attention of the authorities. Gradually they began to realise the imperative need for road improvement.

The press and public continued their campaign. They got so tired of waiting for the Government to take action that committees were formed in several districts to undertake road-making by public subscription. They took the matter seriously and submitted their resolutions to Government. In Capetown a Joint Stock Company was formed to build a road across the Cape Flats over which the main road went. Only £10,300 was raised of the estimated cost of £28,720.

But matters were allowed to continue for some years longer without a definite scheme being formulated. The Governor began pressing the Secretary of State for action to be taken. At last an ordinance was passed in 1843 constituting a Central Road Board and Divisional Road Boards. The Central Road Board, in a sense the counterpart of our present National Road Board, was charged with the improvement and maintenance of main roads. The Divisional Road Boards were charged with branch or divisional roads and had to get the sanction of the Central Road Board before a new branch road could be constructed. Convict labour was employed in roadmaking. The resources of the Central Board were derived from the tolls levied, from the rates assessed and from an annual parliamentary grant. The constitution of these Boards began a new era in the history of roadmaking.

The plan mapped out by the Central Road Board was a comprehensive one, taking in the Western and Eastern Provinces and the north-west. The work took a longer time than at first calculated, and after fourteen years several of the more important sections of the country complained that nothing had been done for them. This was not the first complaint. The people of the Eastern Province complained of the unjust appropriation of the road rates by all landowners and of the small amount spent on their area. One district objected to the use of funds collected in the east for the benefit of the roads in the west. Complaints were heard from time to time and became louder and louder. The system of the Board and the existing law were condemned, and Parliament considered there was no control over the Board and that the power of contracting work should be placed in the hands of those over whom Parliament had control. The Board was abolished in 1858 and the construction, maintenance and improvement of main roads placed under

the charge of the Central Government so far as funds were placed at their disposal. The abolition of the Central Road Board closed an important chapter in the country's history of roadmaking. Notwithstanding their short-comings—owing to the system and the law—the abuse and final condemnation received, they served a useful purpose and performed a service to the country. The work achieved meant much to the economic and social life of the Colony. The production of the country rapidly outstripped its means of transport, time was saved in travel, new villages sprang up and sheep farms extended.

The Divisional Road Boards were abolished at the same time and their duties entrusted to Divisional Councils constituted in 1855. The Divisional Councils were to take an important role in the matter of roads. In 1864 they took over from the Central Government the maintenance of the main roads. Difficulties soon arose. Several Councils refused to take over main roads while others complained bitterly about the condition in which they received them. The grievances were either that the Government had suffered main roads to fall, to some extent, out of repair, and that when handed over were not in their ordinary state of repair; or, that portions of the road which they had been called upon to take over and maintain were not at all or partially constructed. From time to time the same difficulties were experienced. The state of the main roads varied in different districts and repeated criticisms were made by Government Road Inspectors. Many sections of roads were either deep in dust or full of holes and rugged boulders in dry weather, or became the natural course for surface water and were denuded and washed out or became deep impassable quagmires in wet weather. In each case they were so bad that people used them to their great discomfort, peril and jeopardy.

With so many administrative units, each independent, responsible only for that section of the main road passing through its jurisdiction, each one maintaining its portion according to its enlightenment and interest, it was to be expected that the main road as a whole would be defective in parts with surfaces so bad as to be constantly out of repair. There were many faults found, supervision was needed by competent overseers who understood their work and could hold the contractor to his undertaking and keep an eye on the material used. Another complaint was the neglect of proper drainage, material used, and the work being done at the wrong time of the year. But the system of " contracting " or " farming out " the work was condemned by most people and by some it was said to be " the greatest fraud on the public," and opened the way for jobbery. Friends and relations of Council members got the contract, and human nature being what it is, they were looked upon leniently, even when they made mistakes.

From the time the Councils took over the maintenance of main roads in 1864 there was a feeling that this duty should

revert to the Government. In 1898 a Select Committee enquired into the working of the Councils. The evidence showed that there were two schools of thought. One that if the main roads were placed under the Central Government there would be economy and efficiency, the other that the system then in vogue be continued.

The study of the early road system shows that many problems exercised the mind of the authorities. Some of these remain partly or wholly unsolved to-day. The new means of road transportation to-day have produced effects upon road administration undreamt of at the beginning of the twentieth century. But there were problems in the past which are common to the present. Take one instance, that of road widths. Fifty years ago the width of main and other roads was a vexed question. To meet the situation legislation left it to Divisional Councils to determine this in their respective areas. But this did not solve the problem. To-day the National Road Board has considered the merits of steel-tyred and pneumatic-tyred vehicles upon the road and allied to this is the question of the type of road surface necessary to meet the new form of transport. The steel tyre is usually narrow—from 2½ to 3 inches—and means that the load of the cart or wagon is concentrated on a relatively small road area and tends to sink into soft surfaces and crack hard surfaces. They wear and damage the surface. The story of the past tells us the same. During the last half of the nineteenth century, the question of the narrow steel tyre was a matter which perturbed the road engineers. In addition there was the use of the "remschoen" which was described as the "greatest enemy of roads" and this "rude and destructive applicance." The road engineers condemned these road destroyers and wished to see them abolished. To-day the lack of proper maps has handicapped the reconnaissance investigations of the National Road Board. The difficulty of the road engineer under the Old Central Road Board was the same.

Of the many road problems to-day traffic control and the safety of the pedestrian and the traveller for that matter, take a prominent place. It may be of interest to know that our forefathers had the same problems, though perhaps not as acute. Early statutory enactments refer not only to the rights and duties of drivers of vehicles, but also to what has become known in our day as "the rule of the road" and "one way traffic." In 1798 the law laid down that vehicles had to keep to the left and give the right hand to the oncoming traffic. The same law imposed upon road traffic the duty of approaching Capetown from Salt River via the upper road and of leaving the town by the lower road—a clear indication of an early attempt at one way traffic. In the eighteenth century efforts were made to suppress furious and careless driving, and less than a century ago Road Magistrates were appointed to try such cases.

Thus we see that the archives are an aid to reconstruct the past, and show that some of our present problems were the problems in the past.

Conclusion.

The Science of Archives, as we have termed it above, may be likened to a venerable sage who seeks for the authentic traces of man and his doings in the past and, finding them, preserves and zealously guards them. His eyes are glowing with wisdom drawn from the mass of evidence of man's past accomplishments, his failures and successes, as treasured up by him with tender care; ever ready to reach a helping hand to the men of the present day in their struggles to move onward the ship of human progress, often doing so with an encouraging smile and reference to the Solomon of biblical times: " there is nothing new under the sun "; and he appeals insistently to one and all to view the present unfoldment of our grand and wonderful universe in the light of the ages gone by.

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THE HISTORY OF LAND SURVEY IN SOUTH WEST AFRICA

BY

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Presidential Address to Section A delivered 5 July, 1937.

With 1 Text Figure.

In introducing this subject, I propose to outline the events which led up to the time when the foundations of the geodetic survey of South West Africa were laid, and then to indicate the development which has been made with the trigonometrical and cadastral surveys.

Copies of a small scale map of the Territory, indicating the positions of the principal places which are referred to in this paper, are placed at the disposal of members for guidance. A further map of the Territory to the scale of 1/800000, showing the farming area and the main triangulations is also on view.

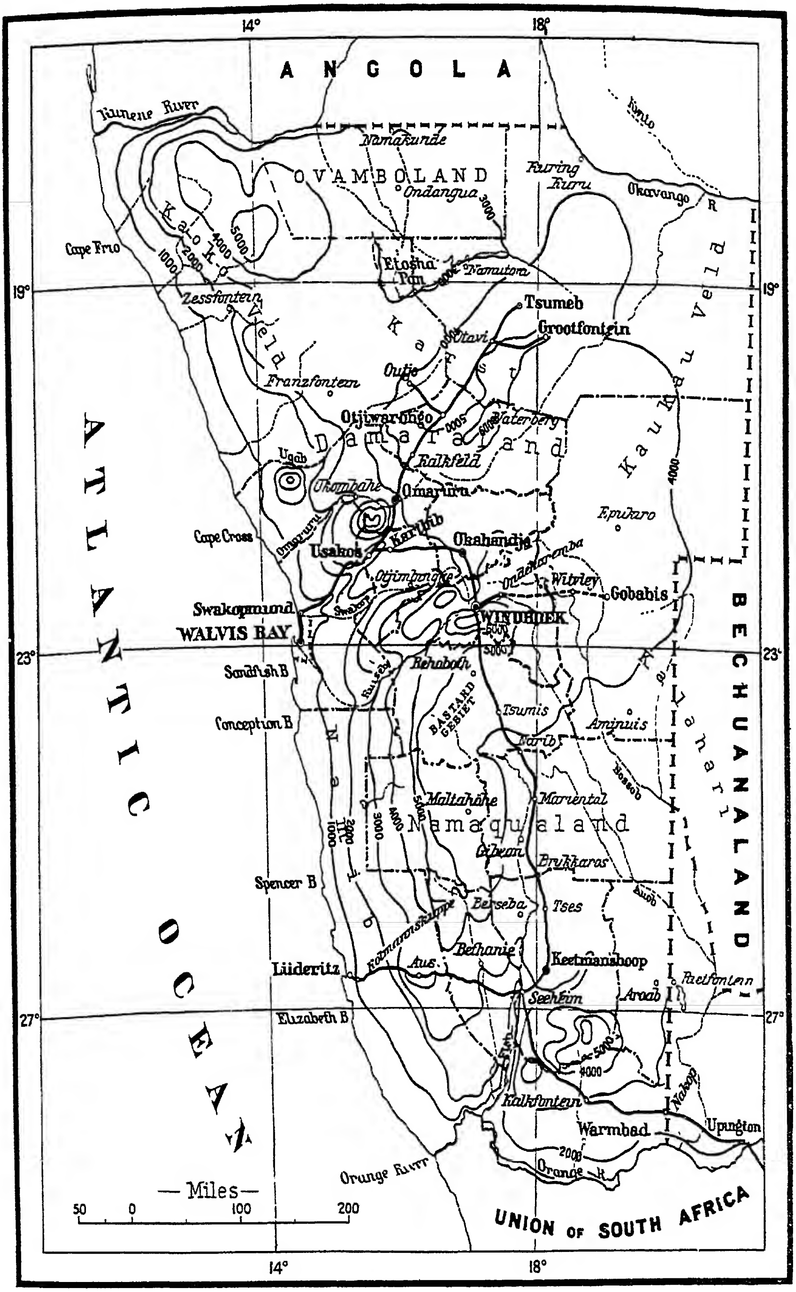
The Territory embraces an area of 317,725 square miles, and while the triangulations do not cover the whole Territory, the area covered is fairly extensive.

When South West Africa was occupied by the Imperial German Government in 1884, no survey work had been done in the country, but in the development of the country a need for surveys to compile correct maps and to obtain registered title to land was soon felt.

The first surveys of farms were undertaken in the year 1894, and owing to there being no primary triangulation, the farms were beaconed off by means of the compass and measuring band. Later in the year 1900 when larger blocks of farms were required, the triangulations were carried out from a local measured base and an arbitrary origin. In this way the district of Karibib and the western part of the district of Okahandja were surveyed into farms of about 5,000 hectares each on a special system called the Uitdraai System. The townships of Karibib and Okahandja were also surveyed on this system.

Further north, in the district of Grootfontein, the South West Africa Company had their land around Grootfontein and Otavi surveyed into farms in 1907 in a similar way.

During the years 1896 to 1898 a triangulation chain of a II Order, called the Wettstein Chain, was undertaken on a special system with one of its stations, Kaiser Wilhelm Berg, as origin. This chain extended from Windhoek south-westwards over a



SOUTH WEST AFRICA Altitudes - - 1000 Feet

distance of 80 miles to Nauchas, in the north-western parts of the district of Rehoboth.

Little further survey work was done on special systems before the geodetic survey was begun, and in carrying that out, the earlier surveys were connected with the primary triangulation.

The Geodetic Survey.

The first geodetic chain undertaken in the Territory was on the eastern border extending from the Orange River northwards to the 22nd parallel of south latitude, during the years 1898 to 1903. The purpose of this triangulation was designed in the first place to define the international boundary between South West Africa and British Bechuanaland. The Border is represented by the 20th meridian of east longitude between the Orange River and the 22nd parallel of south latitude, and by the 21st meridian to the north of the 22nd parallel.

For the purposes of the survey, Commissioners were appointed by the respective Governments under the direction of Sir David Gill, Her Majesty's Astronomer at the Cape at the time. The Commissioners assembled at the place Rietfontein, near the border, in the Gordonia District of the Cape Province. The geodetic survey of the Cape Province had been extended to this point, and the triangulation for the Border chain was extended from these stations at Rietfontein.

North of Rietfontein the 20th meridian crosses the Kalahari Desert, a tract of country intersected with sand dunes and flat and waterless for a distance of 300 miles or more.

The Commissioners, therefore, found it impossible to carry a triangulation along the 20th meridian. Further west the country was more suitable, and the Commissioners had practically no alternative but to arrange the triangulation north-westwards from Rietfontein, and follow the valleys of the Fish and Nosob rivers to Gobabis, and from there eastwards to the Border again, where it is intersected by the 22nd parallel. An offset chain was set out from the Nosob river over Aminuis to the Border.

During the survey the Border line was demarcated with beacons southwards from Rietfontein, at a point opposite Aminuis and in the neighbourhood of the 22nd parallel. The intervening portions of the line were not beaconed owing to the country being heavy and waterless, which made it impossible for the Commissioners to cross with the animal transport at their disposal. The line to the north of the 22nd parallel was also not beaconed for similar reasons. My Administration, however, has found it necessary, recently, to have the line located where it intersects the latitude 19°30′, and I shall be proceeding to this point during this month to determine its position from astronomical observation.

The final latitude, longitude and height above mean sea level of each of the stations of the Border chain were computed

from the geographical co-ordinates of the stations of the geodetic survey of the Cape at Rietfontein.

By this time the country was becoming more developed, and there was a need for better maps and more rigid surveys.

The Imperial German Government, therefore, in the year 1904, took steps for the carrying out of a systematic triangulation of the country which would form the basis and serve all requirements with regard to mapping and cadastral surveys.

The first work undertaken in this connection was the establishment of a double chain of triangles extending from Swakopmund over Windhoek and connecting with the Border chain at Gobabis. The chain covered a distance of 300 miles and involved 33 primary stations. The country over which the chain was carried was favourable for a large scale triangulation, and the triangles were arranged with the lengths of the sides averaging from 30 to 60 kilometres. Twelve arcs were observed of each angle of the triangles, and the average closing error of 41 triangles was 1·03 seconds. After adjustment the probable mean error of an observed angle was 1·29 seconds, and of an observed direction 0·91 seconds.

At Windhoek a base four kilometres long was measured, and the latitude, longitude and azimuth were determined. The correct time used for the calculation of the longitude was transmitted by cable and land line from the Capetown Observatory via Swakopmund.

The observed angles of the triangles were adjusted as a free chain with the length obtained from the measured base at Windhoek.

The Swakopmund-Gobabis chain connected with the Border chain at the stations Schwarzeck and Langer Forst, and a comparison was made with the latitude, longitude and azimuth of the Windhoek station determined from the astronomical observations and from the stations of the Border chain, with the following results:

Windhoek Station		Astronomical.	Geodetic	Difference.
		° ′ ″	° ′ ″	″
Latitude	...	22 33 42·73	22 33 42·64	0·09
Longitude	...	17 05 03·05	17 05 00·95	2·10
Azimuth	...	291 32 39·0	291 32 36·7	2·3

These minor differences proved that there was no material displacement in the geographical position, and it was, therefore, decided to adopt the latitude and longitude of the station Schwarzeck, and the azimuth Schwarzeck-Langer Forst determined from the Border survey as the base for the geodetic surveys of the country.

The Border chain had been computed on Clarke's dimensions of the earth's figure, but as the Imperial authorities wished to use Bessel's dimensions to conform with the surveys in their

other possessions, the Border chain was recomputed on Bessel's dimensions with Schwarzeck as the starting point, for the purpose of the geodetic surveys in the country. The metre was adopted as the unit of measure, and is used still for all land surveys in the Territory.

The two geodetic chains now completed, namely, the Border chain and the Swakopmund-Gobabis chain, afforded a suitable base from which to extend others.

A chain of triangles was extended southwards from Windhoek to Bethanie, while another was brought across westwards from the Border chain in the vicinity of Keetmanshoop to connect with it at Bethanie and close the circuit. This chain was continued westwards from Bethanie to the coast at Luderitz, and a further chain was extended southwards from the Border chain at the Karasberg to link up with the geodetic survey of the Union along the Orange river. In the north a double chain of triangles extending from the Swakopmund-Gobabis chain at Omaruru and following the narrow gauge railway as far north as Grootfontein and Tsumeb has been established.

Heliotropes were used to furnish light from the stations observed, and 12 arcs were observed of each angle of the triangles. The beacons of the stations were constructed of cairns of loose stone built over the centre marks from two to three metres high, with a centre pipe carrying a sheet-iron signal. The centre marks were permanently marked in the ground with iron pegs in concrete or in holes drilled in solid rock. An eccentric mark was placed outside the beacon for control and similarly marked.

The geodetic surveys were carried out by the Imperial General Staff during the years 1904 to 1910, and all records of the field work were sent to Berlin, where the final computations were made

The plan of the geodetic chain of the Union is shown on the map in a green colour, while the Border chain is shown in blue and the Swakopmund-Gobabis chain in yellow. The other chains referred to are printed in light red.*

With the establishment of these geodetic chains the greater part of the occupied area of the territory has been covered, and no further chains have been laid down since then.

In regard to the conditions in the country under which this work was carried out, I would emphasize the difficulties encountered. Conditions were primitive and parts of the country were entirely unoccupied. Until quite recently only animal transport could be used; there were very few roads, which were extremely bad and watering places were scarce. Great difficulty was, therefore, experienced by the field staff in moving about the country, and credit must be given to the officials and staff, who did the pioneer work under such adverse conditions.

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* It was found impossible to publish the coloured map mentioned. The map on p. 19 has been substituted.—Editor.

Main Triangulations.

Having now a net of geodetic work in the country, the main triangulations have been confined to filling the open spaces and breaking down the large triangles with triangulations of the II and III Order.

These main triangulations are based entirely on the framework provided by the geodetic chains and constitute a basis for all cadastral and other surveys.

The trigonometrical surveys to date consist of a primary triangulation having an average length of a side of a triangle of 40 to 60 kilometres; a II Order triangulation with sides of 20 to 30 kilometres, and a III Order triangulation with sides of 10 to 18 kilometres.

A fair amount of the II and III Order work has been completed, but a great deal more requires to be done.

For economic reasons, the beacons of the primary and II and III Order stations consist of cairns of loose stone built over the centre mark with an iron pipe in the centre surmounted by a sheet-iron signal. The centre marks are permanently marked with an iron peg cemented into the ground or into a hole drilled in solid rock. Three reference marks are placed from one to three metres away from the centre mark for control and are similarly marked in the ground.

The observations are made with the 5½ inch Wild precision theodolite, which has proved itself to be very satisfactory. Twelve arcs of angles are observed for all primary work, while in the II Order triangulations eight arcs of angles of directions are observed and six arcs of angles of directions in the III Order triangulations.

Heliotropes are used to furnish light from the stations observed in all primary work, but it is found from experience that they are not necessary in the II and III Order triangulations, except where the background of the signal observed is not clear.

A triangulation net of the III Order was carried out last year at the Waterberg in the district of Otjiwarongo within the frame of five primary stations. The area was comparatively flat and covered with tall trees, and the only means of carrying out the work was by using an observation tower and elevated signals. Twenty-two stations were involved with an average length of the side of a triangle of 12 kilometres.

A signal fixed to the top of a two-inch pipe, 12 metres high, was erected over each station centre, while the surveyor used an observation tower seven metres high, which was transported from station to station. The theodolite was placed on an iron plate fixed to the signal pipe at a suitable height, after removing the upper section and signal, and six arcs of the angles of direction were observed at each station.

The mean closing error of the observed angles of 41 triangles was 1·2 seconds, and after adjustment of the net with the rectangular co-ordinate values of the primary stations, the probable mean error of a direction is 1·04 seconds.

A triangulation net of the II Order is at present being carried out in the Windhoek, Rehoboth and Gibeon districts to fill the open space between the geodetic chains. The reconnaissance and beacon building have been completed and the observing is in progress. The III Order triangulation within the II Order net is being carried out at the same time.

The Co-ordinate System.

Since the establishment of the main triangulations, the Gauss conform co-ordinate systems have been in use. In the first instance, two systems were introduced, namely, the intersections of the 15th and 18th meridians with the 22nd parallel of south latitude as origin. It was considered at the time that, with the large areas to be surveyed and the cheap value of the land, the inaccuracies caused by the greater distortion on the outer edges of the three-degree strip system would be immaterial.

In recent years, however, a change has been made to the two-degree strip system, which conforms with the systems adopted in the Union. The systems now in use, therefore, are the intersections of the 15th, 17th and 19th meridians with the 22nd parallel of south latitude as origin.

Adjustment of the Triangulation.

The adjustment of the triangulations of the I, II and III Order are made by the method of least squares. The II Order triangulation is adjusted within the framework of the I Order, while the III Order triangulation is adjusted within the framework of the I and II Orders.

Trigonometrical Levelling.

The vertical angles between stations of the main triangulation are observed during the same operations as the horizontal angles. Owing, however, to the great length of the sides of the primary triangles, the vertical angles are observed over the sides of the II and III Order triangles. The results of the trigonometrical levelling are satisfactory.

All heights are based on mean sea-level datum obtained from a series of observations taken at a tide guage at Swakopmund, and are expressed in metres.

The highest station in South West Africa is on the mountain Moltkeblick, south-east of Windhoek, the elevation of which is 2,483 metres, or 8,146 feet. The highest mountain in the Territory is the Brandburg, situate about 60 miles from the coast, north-east from Swakopmund. Its elevation is 2,606 metres or 8,550 feet.

Precise Levelling.

The precise levelling was begun in 1906, and the first line levelled was that from the tide gauge at Swakopmund along the railway line to Windhoek, a total distance of 378 kilometres. Bench marks are established at these two centres and at different points along the line. The mean error per kilometre is 1·23 mm.

The elevation of Windhoek railway station is 1,657 metres or 5,437 feet.

At present levelling is in progress from the rail head at Outjo, northwards to the border of Portuguese Angola, a total distance of 420 kilometres. The route being followed touches the western edge of the Etosha Pan and then proceeds north-westwards along the Oshana Etaka, which is one of the principal watercourses in that area. The instrument in use is a Zeiss precision level together with the Zeiss precision staves, which have graduations marked on an invar bar. The equipment is capable of very high precision.

The primary object of running this line of levels is to establish the levels of the Etosha Pan and of the flat country in Ovamboland on a sea-level datum. It is further desired to determine the direction of the flow of storm waters and the differences in altitude between different points in that area.

A site for a large dam on the Kunene river at Olushanja in Angola was surveyed in 1926, and by the extension of the levelling to the border, it will be possible to reduce the levels of the dam site to the same datum.

It is with much regret, however, I am not in a position to give any results at this stage.

Instruments.

Attention should be drawn to the great improvement in survey instruments, which has resulted in increasing accuracy and greater sped in carrying out the field work.

In the earlier surveys the theodolites used for the main triangulations were the 21 cm Hildebrand pattern, owing to the excessive weight of the larger instruments for the mountainous country. In recent years we have been able to procure theodolites by Wild of the 5½ inch pattern, which weigh only 50 lbs. They are capable of high accuracy, and are popular owing to their light weight and their rapidity of manipulation.

The time factor in observing is important in this country owing to the climate, where the haze makes conditions very difficult. The best time of the year for the long distance observations begins about February after the summer rains have fallen, and continues to the end of July.

Topographical Survey.

In 1905 a beginning was made with the topographical survey of the country, when certain areas around Usakos and Omaruru

in the north, the Windhoek district, and the western part of the Rehoboth district and the Gross Karas Mountains in the Keetmanshoop district in the south were surveyed.

The work was carried out by plane-table on 20 minute sheets to the scale of 1/100000.

The Diamond Area No. 1, bordering on the coast line at Luderitz, has also been topographically surveyed to the scale of 1/100000 by the Consolidated Diamond Mines, Ltd. A further topographical survey has been made by the Deutsche Kolonial Gesellschaft to the scale of 1/200000 of the districts of Swakopmund and a part of Omaruru.

The surveys were completed prior to 1920, and no further topographical work was undertaken till last year, when an area of 1,000 sq. miles covering the Klein Karas Mountains in the south was photographed from the air. A topographical map of the area is being prepared from the aerial photographs on the scale of 1/50000.

A further area of 1,000 sq. miles lying between Grootfontein and Tsumeb in the north, and covering the Otavi Mountains, is at present being photographed from the air for geological and topographical purposes.

Steps are being taken to extend the topographical survey with field parties operating with the plane table. Instead, however, of mapping the topography on the scale of 1/100000, the surveys will be done on ten-minute sheets to the scale of 1/50000, and the contour lines drawn at 25 metres vertical interval.

Cadastral Surveys.

As I have mentioned previously, the main triangulations are based entirely on the frame work provided by the geodetic chains. The cadastral surveys also are based on the main triangulations, and the co-ordinate values of all beacons in a system have a common origin.

The triangulation points for the farm surveys are classified as IV Order stations.

The surveys of the Government land into farms was carried out almost entirely by land surveyors attached to the Government staff prior to 1914. The land companies employed private surveyors for their work.

The surveys carried out in the early days on special systems have since been connected with the triangulations.

The greater part of the country extending northwards from the Orange river to north of Outjo and Tsumeb, with the exception of the Namib desert along the coast line and the Kaokoveld, has been cut up into farms. In the south, owing to the arid nature of the country the farms average from 10,000 to 20,000 hectares in extent, while in the central parts they average from

5,000 to 10,000 hectares, and in the north from 3,000 to 5,000 hectares. The total number of farms surveyed in the Territory is 3,906.

Mapping.

Amongst the maps on view is one signed by Theophilus Hahn in October, 1879, which I feel sure will be of particular interest. Mr. Hahn was a missionary, who travelled a great deal throughout the country before its occupation by Europeans. The map was compiled in the Surveyor-General's Office, Capetown, from data supplied by Mr. Hahn, and is remarkably accurate in detail.

Other interesting information is to be found in a "History of South West Africa," by Dr. Vedder, who has lived in the country for many years. This book contains maps which give information of the country as far as it was known in 1820 and during the period from 1820 to 1860. It also contains an up-to-date map of the Territory.

A useful map of South West Africa to the scale of 1/2000000 was prepared by Messrs. Sprigade & Moisel, of Germany, in 1912.

In 1911 a farm area map on the scale of 1/800000 was published, which shows all surveyed farms, railways, towns, magisterial districts and the principal rivers.

No further mapping of the Territory was undertaken till the year 1921, when the Administration brought out a new farm area map. Several revisions have been made since that date, and the latest is at present with the printers. The map on view shows the privately owned land in green colour and land leased by the Government in yellow.

Another map of the Territory prepared and issued by the Administration in the years 1925 to 1927 is the topo-cadastral map. It is prepared in separate sheets to the scale of 1/500000, each sheet covering two degrees. A great deal of useful information has been, and still is, being collected by reconnaissance work outside the surveyed areas for the purpose of this map.

The Administration has, further, prepared and issued the sheet S.F.33 (Windhoek) of the 1 in 1 million international series.

Survey Records.

In conclusion I should like to give a brief account of our system of keeping the records of surveys made.

In the first place the records of all surveys must be submitted to the Surveyor-General for filing of record. When a survey has been completed, the records are indexed and bound in volumes. Every survey station and beacon is given a distinctive name or number. It is the practice to give names to the stations of the I, II and III Order, and numbers to the points of the IV and lesser Orders. The numbering of the points was first arranged for each magisterial district, but this has been found

unsatisfactory, and the practice at present is to number the IV and lesser Order points consecutively in each two-degree square. A beacon index is opened for each such square, in which every station and beacon falling within the area is entered, and the particulars with regard to the co-ordinate values and where the relative angle books and calculations are filled, are noted opposite each point.

For the purpose of recording the farm surveys and triangulations on plan, the two-degree square is divided into farm areas. A general plan of each area is framed to the scale of 1/100000 with the record of the farm boundaries and all survey points. The record of the triangulation is arranged on separate sheets, covering the same areas, and all the survey points and the observed directions are indicated on it.

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SOME GEOGRAPHICAL ASPECTS OF THE PEOPLING OF AFRICA

BY

John H. Wellington,

Professor of Geography in the University of the Witwatersrand.

With 4 Text Figures.

Presidential Address to Section B, delivered 6 July, 1937.

This is the first occasion, I believe, that you have honoured a geographer pure and simple with the Presidency of Section B. I regard it as a recognition of the youthful science of geography, which in recent years has been throwing some light on scientific problems in Africa, as in other parts of the world, and more particularly as a tribute to the work of my colleagues in the Universities of Stellenbosch, South Africa, Pretoria, and now at Capetown, who are helping to elucidate the various adaptational processes in which man is involved in this continent.

For geography is mainly concerned with the physical forces at work in the human habitat, which influence more or less strongly the progress and welfare of man. It is therefore not a self-contained science—if indeed, there is such a thing—but draws freely on the findings of other branches of science, and, with its own proper investigations, applies them to the problem of the human habitat. It is on this account that I have chosen as the subject of my address a matter which is occupying the minds of people not only in South Africa, but, indeed, all over the world. What is the actual state of human settlement in this continent, and what are the potentialities of the continent as a home for human beings? Further, what human types are most suited to the various habitats which we find in the different parts of the continent?

That the continent is sparsely peopled is common knowledge. With its population of between 137 and 165 millions, and a density of about 10 to the square mile, it compares very unfavourably (or favourably, as you look at it) with Europe, which has an average density of about 130 to the square mile, and Asia with about 57. But its density is greater than that of Australia, with just over two to the square mile. We must recognise, however, that in Australia the Europeans are rather more than six millions, whereas the aboriginals number only about 60,000.

In Africa there are only about four million Europeans, of which about two million are in the Union and about a million and a half in the Barbary States. The remainder are scattered over the continent. It is customary to regard as " Africans " the Hamitic and Semitic peoples of Northern Africa, although they are, of course, of Caucasic stock and of Mediterranean type. The Negroes of the Sudan, together with the Bantu of Eastern and Southern Africa, are certainly " Africans," and we must include, too, the Half-Hamites of the East African Highlands, the Khoisan People—Bushman and Hottentot—and the Negrillos of the Congo Forest.

Fig. 1 shows the distribution of the whole population over the continent.* Some interesting and striking facts emerge from this distribution. In the great desert areas the density is naturally very low; in the Sahara, only the oases and a few favourable spots on the Hogar plateau are inhabited at all. In the Kalahari, although it is not a desert in the same sense as the Sahara, the density is less than one inhabitant to the square mile. The controlling factor here is lack of surface water. Possibly this may in time be overcome by boring, but the prospects are not such as to encourage the hope of any great increase in the near future (1).

The zone of highest density is in the Nile Valley, where, in Egypt, rural densities of over 1,000 to the square mile are common in irrigated areas. The highest density actually occurs in the district of Minufiya, where it reaches 1,776 to the square mile. The population of Egypt is steadily increasing. From 2·5 millions in 1800 it increased to 9·7 millions in 1897 and 14·2 millions in 1927, and the birth-rate is amongst the highest in the world.

Higher up the Nile Valley, in the Anglo-Egyptian Sudan, the density decreases rapidly. Along the river, in the Province of Khartoum, it was estimated at 180 per square mile in 1917 (2), but outside the river valley the population density decreases to as low a figure as one habitant to 2·7 square miles in the Province of Halfa. During the wars of the Mahdi and Khalifa the population of the Eastern Sudan decreased from about 8¼ million to less than two millions, but the present trend is upward, and the estimate of the present population is six millions.

In the Barbary States, Algeria, Tunisia and Morocco, densities are generally between 20 and 100 to the square mile, whereas in the southern territories of Algeria and in Tripoli, the conditions are Saharan and the density is in the neighbourhood of 1·5 to the square mile.

I am indebted to Miss Mary Gentles for her help in the preparation of the diagrams.

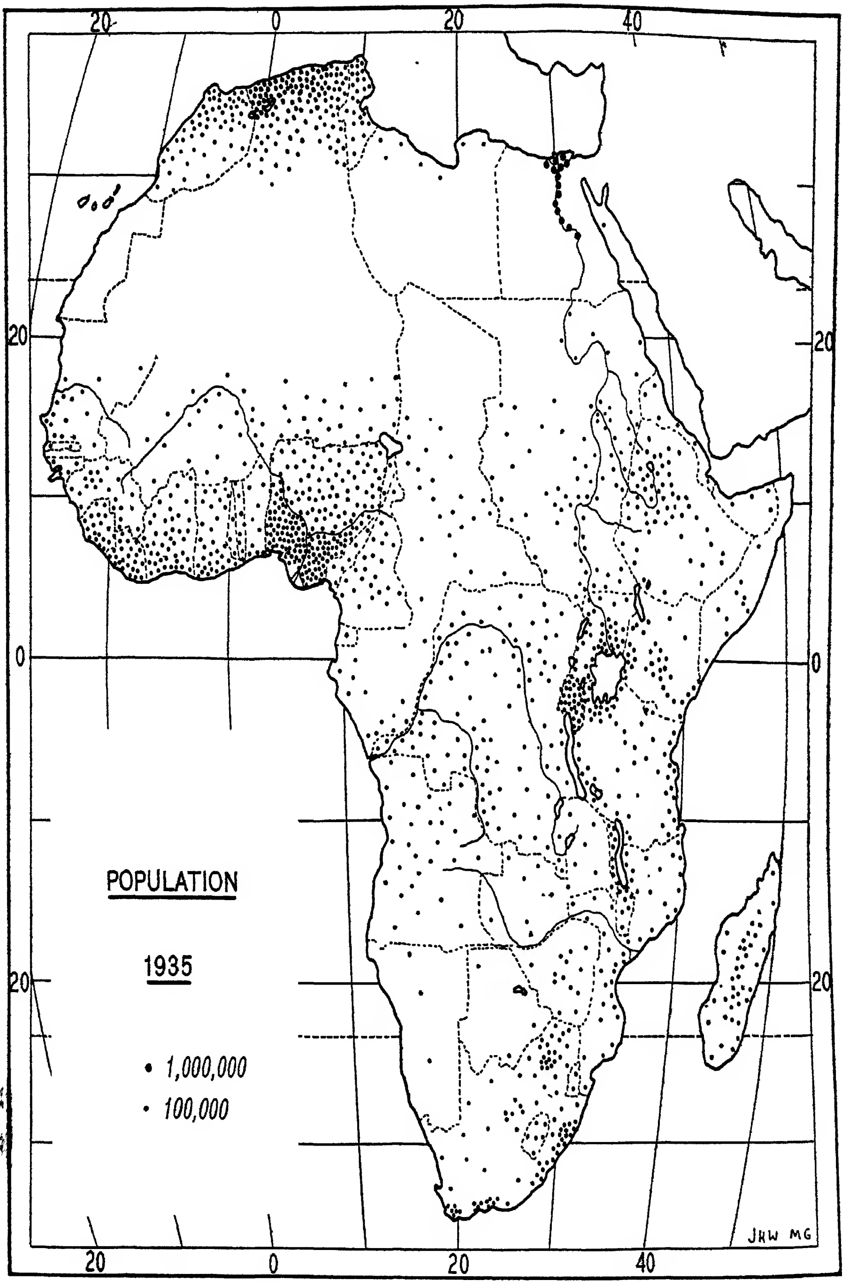

Fig. 1.

Distribution of the Population at the beginning of 1935, based on all available sources.

To face Page 3

To the south of the Sahara conditions become more complex. In Sudan, French West Africa has an average density of about 8, whereas Nigeria has about 50 to the square mile.

The Congo Basin is one of the great empty regions with but 5·7, and French Equatorial Africa has 3·6 inhabitants to the square mile.

Northern Rhodesia with 4·7, Southern Rhodesia with 7·5, fall considerably behind Kenya, 13·7, Tanganyika 13·0, and the Union with 15·5 to the square mile.

As against these meagre densities we may set some of the estimates of the "carrying capacity" of the land in Africa. Two of the most recent attempts to appraise the population potentialities of the continent are those of Albrecht Penck (3) and Alois Fischer (4). Penck, basing his estimate on the climatic character of the earth's regions, considers that Africa has a population capacity of roughly 2,300 million—a greater capacity, that is, than any of the other continental masses, including Eurasia, and a potential capacity of 50 per cent. more than the present total world population. Fischer, on the other hand, bases his estimate on the area of land needed for individuals of various "standards of life," which necessitate 0·9 hectares for the North American, down to 0·3 hectares for the Asiatic-African individual. The population capacity of Africa, thus determined by the conditions within the various regions, is considered by Fischer to be 1,650 millions, Inner Africa (roughly from the Congo-Nile Watershed to the Zambesi) having a capacity of 1,500 millions (instead of its present 79 millions), and Southern Africa (to the south of the Zambesi) 60 millions—an increase of 52 millions over its present population. On a rather different basis, including conditions of climate, coal resources and location, Griffith Taylor (5) considers the capacity of Southern Africa (presumably to the south of the Zambesi) to be 82 millions. In this estimate Rhodesia has a capacity of 40 millions and Natal 14 millions.

It is not my intention of attempting here yet another prophecy of the ultimate possible population of the continent. I feel that, for the present, what is most needed is a knowledge of the actual facts which have influenced, and which are now influencing, the peopling of the continent. Of these the most fundamental are probably the climatic factors.

Climatic Factors.

A difficulty which we encounter at once in analysing the climatic influences is the lack of climatic records for most of the continent. A good many of the generalisations about the climate of Africa must perforce be intelligent guesswork. Happily, this difficulty is diminishing, for the great central and eastern tropical uplands are now investigated by the British East African Meteorological Service. As settlement and economic development

proceed in other parts of the continent, doubtless the increasing number of meteorological records will enable us to get a clearer picture of the climatic environment.

The most obvious control of the density of the rural population is rainfall, and, with it, water supply. Mere mean annual rainfall totals, however, are only useful in a general way. We must know how the rain is distributed, what its intensity is, and its incidence or mode of occurrence. On the southern border of the Sahara the zones are fairly distinct; with a rainfall of between about 5 and 20 inches, a steppe or dry grassland type of vegetation is produced, in which human beings must generally adopt a nomadic or semi-nomadic type of existence, and the general density of population in these areas is about 3 to the square mile. There can be no safe generalisation, however, on such a relationship, for in parts of the Kalahari, with rainfall of about 20 inches, the surface sand inhibits anything but the most sporadic occupation of the area. On the other hand, in little Namaqualand, the dry north-western part of the Cape Province, an important industry is the growing of winter wheat with annual rainfall amounts in the neighbourhood of 5 inches. But even so, the population density here is rather less than 3 to the square mile. Except in the case of allochthonous rivers like the lower Nile and the lower Orange, where irrigation can be practised, rainfall is certainly a limiting factor in the population density of the continent. But in regions of high rainfall the density appears to bear little relationship to the rainfall, as we have seen.

A more reliable indication of the value of the rainfall would be given by the evaporation factor in various parts of the continent. In the Union there are several gauges; the records show amounts of evaporation from a free water surface varying from about 72 inches for the year near Port Elizabeth to 108 inches at Buchuberg, in the Orange River valley, and doubtless higher totals than this will be observed. Seeing that maize, in good growing condition, transpires from its leaf and stem surfaces, the equivalent of about 5 inches of rainfall during the growing season, it is obviously of importance to know what proportion of the rainfall is being evaporated from the soil surface and to what extent the value of the rainfall is discounted by this process and by the run-off. Such factors are practically unknown for most of the continent.

Hirth (6) has attempted a map to show the approximate relationship between rainfall and temperature by using "Rain Factors," obtained by dividing the annual rainfall in millimetres by the temperature in degrees centigrade. He has thus drawn "isonotides," or lines of equal humidity.

The meteorological records available for this purpose are, however, too few to give an accurate demarcation of such regions, and Hirth himself regards his map merely as a pioneer attempt.

It is significant that Knox's maps (7) of the monthly rainfall of Africa, published in 1911, are still in general use.

Another hyetal factor of great importance in considering probabilities of settlement is the reliability of the rainfall. In the Union, Plummer (8) has been the pioneer in this work, and more recently Schumann and Thompson (9) have carried the investigation further. In South West Africa and Southern Rhodesia, too, the subject has been investigated as closely as conditions will allow, but the difficulty in all areas, outside the North African areas, is the shortness of the records. All over the savanna and steppe areas of the continent, the irregularity of the rainfall is justly blamed for some of the failures in agriculture, but we are not yet in a position to recognise the many regions which are fortunate in the regularity of their rainfall and those which should be avoided by cultivators on account of rainfall unreliability. The tentative map by Biel (10) is put forward by the author as a "first approximation." It will undoubtedly be greatly modified as the work of the various colonial meteorological services develop.

Temperature and Other Climatic Factors.

The influences of air temperature on econmic development and on human settlement are not so direct as those of rainfall, but they are important, and their effects are far-reaching. In determining the limits of tropical and sub-tropical productions temperature is generally the decisive condition. Tea, coffee, cotton, sugar, sisal and the oil palm are all limited in their distribution by temperature. These limits are fairly well known in Africa, and any settlement based on such cultivation must be confined, of course, to the warmer zones of the continent.

But students of settlement are becoming conscious of more fundamental effects than these, and the question which is more insistent in the minds of geographers and physiologists is: In what ways is the tropical climatic environment affecting the health and the well-being of Africans and Europeans? Everyone who has lived in a tropical climate knows perfectly well that the climatic environment is something to be reckoned with, and that unless one can come to terms with it the best course is to quit, even at a material sacrifice. But until recently the causes of even the most evident effects were little understood, and a violent controversy has been carried on between the pro-tropical and the anti-tropical schools. Even now, only a beginning has been made in the scientific study of tropical environments, but the progress is worth considering.

Let us first glance at some of the broader aspects of air temperature distribution over the continent. Keeping in mind that the only extra-tropical inhabited areas of the continent are the northern extremity, to the north of the Sahara, and the southern extremity, consisting of the greater part of the

Union, we are prepared to find over most of the continent temperatures considerably higher than those of temperate countries. Even if we keep to the highlands, where possibilities of European settlement are greatest, we find that the main differences from English and Central European thermal

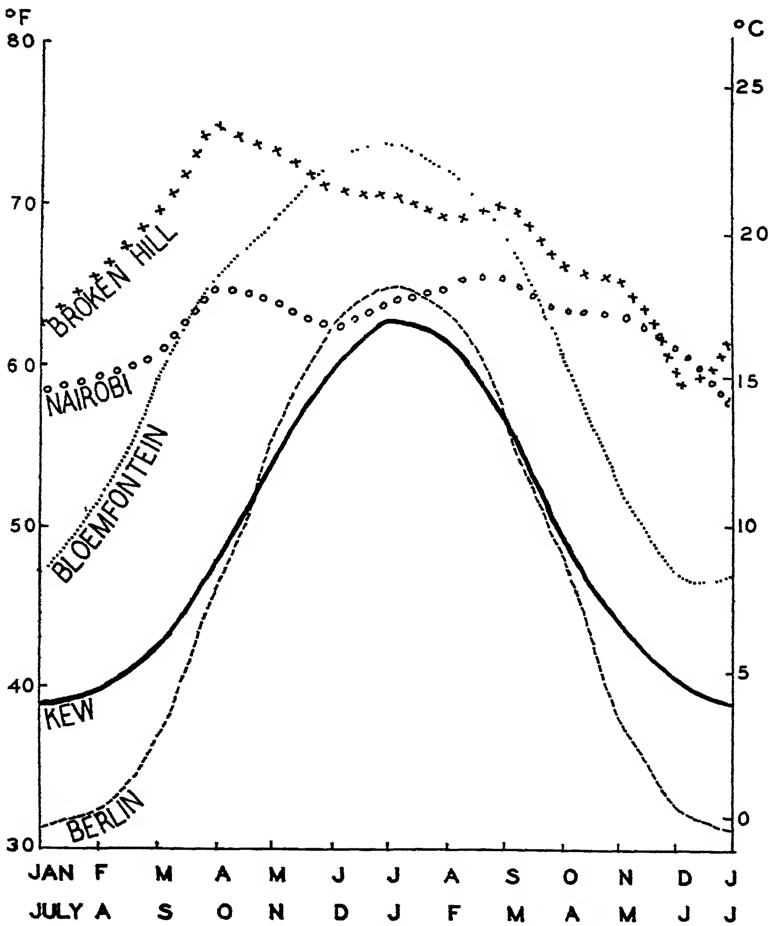

Fig. 2.

Curves of mean monthly temperature at Kew (London), Berlin, Bloemfontein, Broken Hill and Nairobi. The year is taken from July to June for the African Stations.

conditions are the generally higher temperatures of the African highlands and the greater length of the hot season. In Fig. 2 it is apparent that even for Bloemfontein, with its highveld position, the average temperatures throughout the year are some 12° to 15°F. above those of London, and some 10° to 18°F.

above those of Berlin. Perhaps the contrasts are even clearer if we consider the mean maximum temperatures, which are more nearly representative of the working conditions of people. In the warmest part of England—the valley of the Thames, near London—the July mean maximum temperature is about 72°F. (22·2°C.), and the mean minimum about 53°F. (11·7°C.) (11). For Bloemfontein in January the corresponding temperatures are 87° and 60°F., and for Broken Hill in October 88° and 65°.

But temperatures alone give only a partial indication of the comfort and efficiency resulting from atmospheric conditions. The cooling power is, of course, related closely to the relative humidity and to air movement.

The low relative humidity of the air in the African plateau during the dry seasons is well known. At Bloemfontein it is about 40 per cent. in the dry winter months, but over 60 per cent. during most of the rainy season. At Broken Hill it is about 40 per cent. in September and over 80 per cent. for the three rainiest months (12).

In the highlands of Eastern and Southern Africa, therefore, we are dealing with areas in which the temperatures are significantly higher than the summer temperatures of Great Britain and Central Europe, and in which the seasonal variations diminish towards the Equator. The evenness of the temperature curve for Nairobi (Fig. 2) brings out this lack of "winter" in the tropical regions near the Equator. By contrast with this even march of the mean monthly temperature, the diurnal range is remarkably high. At Nairobi, for example, the range between the hottest and coldest months is less than 7°F., whereas the average daily range is about 16°F. (9°C.). We may compare this diurnal range with the annual range of about 23°F., at Greenwich (12a).

Another factor of great significance, but difficult to measure satisfactorily, is the actual heat-imparting power of the direct rays of the sun. The black-bulb thermometer is somewhat unsatisfactory for this purpose, but the readings, in default of more accurate methods, give an approximation of the general conditions.

Thus the mean daily maximum black-bulb thermometer readings of the three midsummer months for a period of six years give 122·2°F. for Greenwich, and 149·6°F. for Kimberley (13). There is no doubt that this high intensity of the direct rays of the sun constitute a factor of major importance in the African climatic environment.

With these conditions in mind we can consider some of the established physiological effects of high temperatures upon the human organism. In a recent paper (14) Lee has shown that after the immediate passive reactions, viz., a rise in skin temperature and increased evaporation of moisture on the skin surface, have taken place, the body attempts to adapt itself to

a hot atmospheric environment by primary and secondary activities. The primary activities include the flushing of the skin with blood ("cutaneous vasodilatation"), by sweating, and by primary water shifts, leading to an increase in blood volume. How these processes are set in motion is obscure, but they appear to be controlled by the effect of a rise in body temperature on nervous heat-regulating centres.

If these primary adaptations are insufficient to maintain the normal body temperature they are followed by "secondary active adaptations."

According to Lee, these include first a rise of body temperature, which, incidentally, is accompanied by an increase in the heart rate.

The endocrine balance is also affected. The excretory activity of the thyroid gland and the suprarenal medulla is reduced, but whether this is brought about through the nervous system or directly by the rise in blood temperature is not known. Lee regards this alteration of the endocrine balance as one of the chief factors in acclimatisation; by the reduction of the thyroid and suprarenal excretions, the metabolic activity of the whole body may be lowered and a decreased appetite follows. Decrease of appetite is regarded as a truly adaptive phenomenon, but it "often reaches a degree inimical to the organism . . . and the desire for and ability to sustain voluntary activity is diminished" (14). This is obviously an effect of very great importance, and as we shall see later, may account for the lethargy of Europeans and Africans which is so often noticed in the tropics. Under conditions of great heat the equilibrium between the body and the environment may thus break down and the temperature of the body may rise to produce a state of hyperpyrexia or "heat-stroke," in which the nervous system is the first part of the organism vitally affected. It is known that the neuroglobulin separates out at 108°F., so that there is a real decomposition of the nervous system at this body temperature. One of the causes of hyperpyrexia is severe physical work in a hot environment. It is recognised that a contributory cause of these effects may be a bad circulation of the blood, which itself may be caused by injudicious eating and drinking and other circumstances. Even if we pass over the electrolyte imbalance and the super-dehydration, which Lee mentions as other causes of the breakdown of the equilibrium between the body and the atmospheric environment, there is sufficient here to show the strain on the body during periods of long-continued high atmosphere temperature.

The part played by the skin in cooling the body is, of course, fundamentally important. The flushing of the skin with blood is, as we have seen, one of the first of the adaptive mechanisms for the cooling of the blood and for the production of sweat. The work of Hill and Campbell (15) shows that the

skin is heated not only by the infra-red rays, but that the luminous rays have the effect of heating of the sub-cutaneous tissues to a higher temperature than that of the cutis itself. It seems probable that in this lies the significance of pigmentation.

How pigment is produced in the skin is still not fully known, but its function—or one of its functions—is apparently the protection of the deeper tissues from this excessive heating. Balfour states that " light rays pass through the cutis till they strike the pigment layer, when they are converted to heat. In the case of the white skin the light rays pass right through, and the conversion into heat takes place as the result of the action of the blood pigment " (16). The investigations of Aron (17) in the Philippines confirms this advantage of dark-skinned over white-skinned people in the tropics, but, in the case of monkeys, a certain degree of adaptation is apparently possible through diet and gradual exposure. The increase of pigment in the skin of Europeans in the tropics is apparently a similar adaptation, and it seems possible that the reluctance of many women to " burn brown " may partially account for some of their greater difficulties of acclimatisation.

The effects of the ultra-violet rays on the body in general, and the skin in particular, are still not understood, but recent advances in bio-chemistry have made it evident that strong ultra-violet rays increase the cholesterol content of the skin, and that the ergosterol is activated to vitamin D. This chemical process is apparently assisted by a high temperature of the skin.

An interesting adaptation in tropical regions is the reduction in body weight which takes place in individuals who become acclimatised. The greater the body weight in relation to skin surface, the less is the effective cooling efficiency of the skin processes. The observations of Eijkman in Java on Natives and Europeans and the experiments of Sundstroem on mice (18, p. 332) show the disadvantage in hot climates of great body weight in relation to skin surface. Probably this has a bearing on the fact that lean, spare types of men appear to be best adapted to the tropical environment.

That the constitution of the blood is affected by hot environments is shown by Sundstroem (18, p. 342), who finds that both in his experimental rats and in humans a reduction of the acid-soluble and lipoid phosphorus of the blood takes place in a tropical climate, and he finds a connection between this reduction and the cooling power in four types of environment.

Sundstroem believes this to be one of the more important effects of the tropical climate, but apparently its significance is not yet clearly understood. There appears to be no reduction of the number of red corpuscles in the blood in hot environments, but Sundstroem found a definite leucopenia, or poverty of white corpuscles, produced by an artificially human hot climate. Human

beings having such a low leucocyte count in the tropics, however, generally become normal in this respect on their return to a cooler climate.

Possibly this leucopenia is connected with the white count results obtained by Stammers and Sachs in Johannesburg (18a).

Of fundamental importance in considering the peopling of tropical Africa with both Natives and Europeans is the influence of hot climates upon reproduction. In his experiments on rats in an artificial humid tropical climate Sundstroem (18, pp. 348-9) found that sterility in the males often results from the atmospheric environment, and that females in similar conditions "have only in two instances proceeded to full term and resulted in the birth of living young." Later experiments, however, showed that the reproduction function may considerably improve in the second "descendant" generation, and that an increase in the cooling power of the atmosphere by fanning led to improved results.

In human beings such effects are difficult to estimate, and are often masked by other influences. It is known, however, that sterility in rams results from subjecting the testes to "a degree of heat as mild as that normally existing within the body cavity" (19), and the sterility in man associated with cryptorchidism suggests comparable human effects. An investigation of this factor would probably throw new light upon problems of reproduction in the tropics.

No such direct effects are to be found, of course, in the female gonads, although, as we have seen, hot climates do definitely affect the thyroid and suprarenal glands, and there is some evidence to show that the pituitary is also affected (18, p. 352). But what the resultant effects are in the functions of the ovaries is not clear. That reproductive functions in females are profoundly affected by hot climates is, however, well known. The early age of menstruation in native girls may not be due to climatic influences alone, of course; physical, social and nutritive influences undoubtedly play a large part here, but the evidence examined by Steinach and Kammerer (20) lead to the conclusion that a moderately severe climate leads to a lowering of the age of maturity, whereas severe tropical conditions may raise it.

With regard to the fertility of women in the tropics, Castellani, Chalmers and Mackinnon show that "a hot climate predisposes to sterility of women, to menstrual abnormalities, to abortions. and to post-puerperal haemorrhages" (18, p. 347).

Balfour also confirms the strain on the generative system of women, but he states that "there is no means of actually determining how far this strain is likely to affect the race springing from them" (16, p. 243).

Whether acclimatisation may improve these conditions is not certainly known, although the facts presented by Cilento

(21) that acclimatised European women in tropical Queensland have a higher actual fertility than the rates for Australia as a whole seem to point in that direction. It would be of value to know to what extent the apparently high abortion rate among native women in Africa is due to climatic influences, as distinct from pathological conditions.

When we come to consider the effects of tropical climate upon the nervous system we are still on controversial ground. That hot environments have a deleterious effect upon the nervous system is borne out by some of the most careful observers of human life in the tropics.

No one who has resided for a considerable time in the tropics will doubt the nervous strain, for example, accompanying the high temperatures during the period immediately preceding the summer rains. Whether the strain is the effect of the heat alone it is impossible to say; electrical conditions probably also have an effect, but here again what precisely these effects are is not yet understood. The strain on the nervous system, however, appears to be greatest in the drier and windier tropical regions. Possibly the fact that skin, when it is dry, is a bad conductor of electricity has something to do with this, for Dugge found that during the dry Foehn wind the direct current resistance of the skin is increased and the human body becomes strongly charged with electricity (21a).

The recognition that the body adaptations to a hot environment are probably activated by the sympathetic nervous system may provide a clue to the problem of tropical neurasthenia. Is tropical neurasthenia the result of a too constant demand on this function of the nervous system? The difficulty of isolating a factor of this kind is very great, since nervous exhaustion may be accelerated by various other factors which do not appear to be directly connected with climate.

Balfour refers to an exhaustion and neurasthenia which results from excess in venery more speedily in the tropics than in temperate countries (16, p. 243). I have heard a medical missionary refer to such general exhaustion as a frequent cause of great psychological distress among Natives; possibly such effects are indirectly due in part to climate, but my own experience leads me to believe that the more enlightened African Natives realise that an improvement in these conditions can come about through spiritual development. "In these matters," a native once said to me, "we Africans are weak; we need your help." It is at once an opportunity and a challenge to Europeans in Africa. There are, of course, many other possible causes of tropical neurasthenia, including, in native life, the haunting fear of the spirit world.

In connection with European conditions, Ward (22) uses a significant term, "the climate of loneliness," to describe the effects of isolation on Europeans in the outposts of

civilisation. Another factor with Europeans is undoubtedly economic in character and connected with the severity of conditions of settlement in some of the tropical areas (23). As a settler in Kenya said to me: " If I have good crops and fair returns life in Kenya is good, but when the rains fail and the crops die, and my overdraft grows, do you wonder that I am possessed by ' furor Africanus '? " It is, indeed, difficult to distinguish between the various kinds of neurasthenia in the tropics.

But to return to the physical environment, there is abundant evidence to show that the tropical sun has a direct effect on the whole network of peripheral nerves. This effect seems to be at first stimulating but afterwards depressing, and a neurasthenic condition supervenes if the depression is exaggerated (16, p. 244).

Altitude.

Another difficulty here is to recognise adequately the part played by altitude in these nervous disturbances. Since the areas most suitable for European settlement in Africa are highland areas, these influences are of importance in our review. That the sunlight is more intense at high altitudes is, of course, well known, and in particular the ultra-violet content is increased (24), which, as we have seen, leads to the increase of ergosterol in the blood. The nervous reactions of individuals to increase of altitude appear to vary very greatly. Some people show marked nervous excitement even at altitudes of 5,000 to 6,000 feet. " The outlook alters, and there is an increased enjoyment of life. At greater altitudes sub-maniacal states with increased irritability alternate with moments of depression, particularly when people are confronted with physical exercise " (25, p. 141). The extreme conditions are experienced among the inhabitants of the high plateaux of the Andes and on the Mexican plateau, where mental lability and weakness, irritability and hysteria are said to be the most common complaints, although, as Jourdanet says, there are probably other contributory causes. It is significant, too, that the symptoms of mountain sickness occur in non-European inhabitants of mountain regions if they climb about 3,000 feet above their usual dwellings. The second British Mount Everest Expedition, however, showed that a chronic form of mountain sickness develops some weeks after arriving at a high altitude, the symptoms only disappearing after the return to low altitudes. Similar symptoms have been observed in horses and cattle in Mexico and Algeria, and at altitudes of 8,000 feet in southern United States of America. At similar altitudes in the Alps, Adametz found the same symptoms in young cattle, sometimes resulting in death. Here again the disease persists until the return to the plains (25, p. 155).

The only considerable areas of colonisation at altitudes of 8,000 feet in Africa are in Abyssinia, Kenya and the Eastern

Congo, but the occurrences mentioned above are sufficiently definite to suspect some nervous reactions to altitudes of five or six thousand feet. But what these reactions are is not clear; the probability is that they vary very greatly with individual constitutions, and my own experience leads me to believe that at altitudes of about 5,000 feet the nervous effect may be healthily stimulating to persons of naturally phlegmatic constitutions. It seems to be also established that, in spite of the higher red count and the consequent increased viscosity of the blood, there is no hypertrophy of the heart at moderate altitudes (26).

But in the Andes, at altitudes of 10,700 feet, Monge and his collaborators (27) found a lowering of the pulse-rate at rest after exercise, and in 90 per cent. of the cases examined, fatigue accompanied the tachycardia.

Tropical Acclimatisation.

To collect all that is known of the various climatic influences and to attempt a pronouncement on the possibilities of human acclimatisation in Africa would be far beyond the scope of this address and the capacity of your sectional president. But I think that it might be profitable to review a few of the facts and opinions.

In his book, "Civilisation and Climate," Huntington has arrived at the conclusion that, taking people by and large, the optimum temperatures for physical and mental work are respectively about 64° and 38°F., and that these conditions are generally likely to be found where the mean annual temperatures are about 51°F. (28). Further, an important point in his thesis is that in the ideal climate the weather must be variable—there must be the stimulus of frequent change. In such climates, he shows, the great progressive human movements are located. Climates which are too genial, and in which there is little change of weather, are, according to Huntington, degenerative. In this way the climate of South Africa is regarded as "pleasant," but lacking the "stimulating qualities which are so important in Europe and North America." Showing that the Europeans have moved from a more stimulating climate to a less stimulating one, whereas the Natives have done the reverse, he states of the Europeans that "the weaker ones are being weeded out and prepared for destruction. What the final result will be no man can say. It depends upon whether we can devise a means of preventing the deterioration which now seems to attack a portion of the population when people move from a good climate to a worse" (28, pp. 45-6). Huntington's opinions on the influence of climate generally have been gaining support from many quarters, and it is impossible to sweep his criticisms of our climate aside with the disrespect that modern nationalism in all parts of the world would commend. The difficulty in

matters of this kind is to take a detached attitude, for if a man is fired with the purpose of helping to evolve a "White South Africa," or a "White Australia," it requires something more than the cool impartiality of the scientific spirit to state the truth; it requires courage to enable him to face the hostility of his own countrymen. One thinks with pride of geographers who, rather than twist and distort the truth as they have seen it, have preferred to incur the odium reserved for traitors and have accepted banishment from their native land.

Huntington, as far as South Africa is concerned, is a detached observer, although he appears to be basing his opinions on climatic records and "poor white" reports. He does not state if he has had any first-hand experience of conditions in this country.

With the Barbary States of North Africa we may claim in the Union to be one of the African countries where, at least, settlement has been little affected by climatic handicaps. And yet, I think, there is everything to be gained by an impartial examination of the facts. Has South Africa, in fact, a "pleasant climate" which is leading to the degeneration of the European population, as Huntington asserts? Some facts will be accepted by most South Africans. No one would be prepared to state, for example, that the climate of Komatipoort, or of the eastern low veld of the Transvaal generally, is stimulating either to Europeans or to Natives. I have never heard a European assert that the summer climate of the coastal region of Natal is bracing. And even men who have been born in the area, and who feel bound to defend it from possible aspersions by geographers and others, will scarcely go so far as to say that the summer climate of the Limpopo Valley, to the north of the Zoutpansberg, is bracing in summer. And few people would go further than to say that the winter climate of these areas was more than mildly stimulating.

By contrast, the climate of the High Veld is in winter unquestionably severe at times, even to those born and bred in England. At these altitudes of 4,000 feet and over the sun is rarely warm enough in winter to be enervating. There is an unquestionable stimulation in the winter climate, which affluent Europeans sometimes seek to avoid by migrating in the winter to the summer conditions of European countries. In the summer, it is true, there are spells of hot, enervating weather, which, however, are often broken by thunderstorms. The weather is not the regular daily cycle of the equatorial regions, but an irregular cycle of heat spell and rain spell. There is a good deal of real "weather" in the summer climate of the High Veld, and heat conditions are far more tolerable there, I believe, than, shall we say, in Chicago.

In middle-veld areas, with altitudes of 2,000 to 4,000 feet, it is true that midday summer temperatures are often in the

nineties, and it is the custom for people who can to rest in the early afternoons. So it is in Italy, for example; indeed, the summer temperatures resemble very closely those of some of the Mediterranean countries.

I believe that there is very little danger of Europeans degenerating on the High Veld, but in the lower regions of the eastern and northern parts of the Union there is a real danger, to which is added the further handicap of malaria, which we shall consider presently. No one, I feel, who has seen school children in the northern low veld, yellow with malaria, and listless on account of the continual heat, can have any doubts about the degenerating effects of this environment. Improved nutrition and physical exercise can doubtless accomplish much in such children, and the results of such improved conditions and transference to the High Veld environment have been very encouraging (29), but the question still is whether these improvements can be maintained in the original environment.

The "poor white" problem is more complicated than a simple study of temperatures and humidities would lead us to believe, and its complexities have been set out in detail (30). The isolation of some of the rural communities, the character of the early settlers and their aloofness from modern developments, the rapid industrial and commercial progress of the country—a progress to which some sections of the rural community have been hostile; these are some of the non-climatic factors which have played a large part in the formation of a poor white section of the community. The presence of native labourers, too, in spite of the advantages it has meant to the country, has probably lessened the hardiness of our rural communities. Even if our material progress had been delayed thereby, it would doubtless have been better if we had had to undertake the hardest physical labour ourselves. This seems to have been the key to whatever success has attended the white settlement of Queensland, where the tropical regions are being developed on the basis of European labour. There is thus a chance of complete acclimatisation and the survival of types most capable of complete physical adaptation to the tropical environment.

There is, however, another climatic factor which is often overlooked in considering the success of settlement. A considerable number of poor whites derive from regions of low and unreliable rainfall in the Union. There is a continual risk of crops and of herds, and a continual hope that next year's rainfall will make up for the past year's drought. It is a gamble with nature, and, as in all gambles, there are those who lose. Perhaps the lack of nourishment, which often accompanies the times of drought, lowers the physical and mental tone and leads to a slow degeneration. Natives suffer in like manner; extreme poverty levels human beings of any colour.

So long as we hold on to these "droughtlands," with farm units too small to provide in two years of good rainfall enough to tide families over three years of drought, so long shall we have rural communities who will find it impossible to remain independent and self-supporting. This, I feel, is a problem that concerns all those parts of the continent in which a high variability of rainfall is a characteristic of the climate environment. It is perhaps what a recent writer in Kenya is referring to when he says that he does not consider the prospects are at all good there "for the man who has only moderate means, unless this includes an absolutely assured income which is not going to be affected wherever he lives" (31).

It is of some interest and value to compare conditions of settlement in the East African Highlands with the highlands of the Union. An account of these conditions was given to the International Studies Conference in Paris last month by an observer who is at once impartial and disinterested, and who has spent three years studying these conditions at first hand (32). Salvadori finds that there are three periods of acclimatisation on the high plateaux of Kenya. The first is a short period of a few days only during which the body adapts itself, generally without much inconvenience, to the high altitude. Then follows a second period during which the colonist feels full of energy. His health is good, owing to the stimulating and tonic effect of the solar radiations. This lasts for about six to eighteen months, according to the physical constitution of the individual, and according to his occupations and habits. Sometimes this second period of exhilaration lasts for several years, but "the percentage is infinitely small." Then follows a third period, the longest, which lasts until the individual leaves the country. "It is a period of physical and mental depression, which passes into a physical and mental degeneration of the colonist. The organism, which is exhausted under the effect of the altitude and solar radiations, becomes weak. The activity and the energy which were so accentuated during the second period disappear. All work, both physical and mental, becomes distasteful. The physical and intellectual slackness which characterises those who have lived long on the high plateaux is not due to the nature of the colonists, but solely to the physical factors which have been mentioned. The tendency, so widespread in East Africa, among the colonists, to make an excessive use of alcoholic drinks is due to the unconscious desire to counteract the state of depression caused by their long residence." Salvadori also questioned the Italian workers who had returned from the Abyssinian Highlands, where they received pay far higher than they could get in their own country. Yet, after a few months, they had returned. They all agreed that the reason for their return was that after five or six months on the plateau they felt compelled to leave it because their health began to go (commençait à s'affaiblir). The proposed occupation and settle-

ment of Abyssinia by five million Italian colonists in five years is evidently not going to be quite so simple as was at first supposed.

Of even more direct interest to us in the Union is Salvadori's observations on the conditions of the Boer settlements in Kenya. " They are descendants of a race which has become acclimatised in Africa for several centuries; they came to Kenya more than 30 years ago to follow agricultural and pastoral occupations to which they were already accustomed in their own country. Hit by the economic crisis, they found it impossible to pay for native labour. They did not even attempt to work themselves; they let their homes fall into ruins; they no longer took care of their beasts; they were content to feed like the natives on a little mealie meal. By a little effort they could have improved their conditions and at least procured for themselves better food. They did not do it simply because the climate of the high plateaux had robbed them of all energy. They present a living picture of what awaits colonists whose private income is not sufficient to allow them to maintain a standard of life necessary to enable them to resist the climate."

Salvadori remarks on the signs of physical and mental degeneration in the children of parents of all nationalities in Kenya who are unable to provide an education overseas. He concludes by affirming his belief that Europeans can only escape the ill-effects of the climate on these high plateaux on the following conditions:—

1. They must do as little manual labour as possible. " A European will not suffer from the effects of the climate if he performs the function of a director of labour."
2. They must have healthful and abundant food. " The régime, often extremely simple, of the peasant classes of certain European countries, such as those of the south-east, is not sufficient for the high plateaux of East Africa."
3. They must be able to rest whenever they feel the need of it.
4. Every year the colonist and his family must spend some weeks in places of lower altitude.
5. Every three years they must stay for several months in temperate countries.
6. Their children must spend a part (not less than a third) of the period between the ages of 5 and 16 in a country of the temperate zone.

These observations of Salvadori should, at any rate, give pause to those who are ready to advocate the rapid colonisation of the tropical plateaux of Africa. It seems as if the process must be slow if it is to succeed, and that there will be a process of elimination of those unsuited to the environment.

Some possibilities of progress become apparent, however. There would seem to be a greater self-discipline needed in the struggle against adverse environmental conditions. The African Native is better equipped somatically to withstand the severe tropical conditions, and only the fittest of the Europeans will survive in the struggle for existence. Whether even physical, mental and moral soundness will enable the European to colonise tropical Africa as an independent worker remains to be seen. Perhaps, as in Queensland, a new European type will develop (32a), or perhaps, as Balfour suggests (16, p. 247), if acclimatisation prove impossible, perhaps the surviving types will be half-breeds, as in South America. The only real test is that of a colony of European labourers proving their ability to live by the sweat of their brows, for, with the inevitable development of the African Native, the European cannot remain permanently an overseer and director. The next century or two should show what is possible; at present we can only attempt to estimate the forces involved.

Biological Factors.

If the effects of climate on settlement are somewhat uncertain, the influences of some biological factors are all too evident. Of these, the anopheline mosquitoes, the vectors of malaria, are the most widespread scourge in Africa, the two chief carriers being *Anopheles costalis* (*gambiae*) and *A. funestus*.

Gambiae breeds in stagnant water, and consequently is most active in the rainy season, where it works havoc in the warmer areas of the Union after the summer rains (33). The extent of the breeding grounds of *gambiae* in the Transvaal have been investigated (34), and attempts are now being made to solve the problems connected with its distribution in Natal. In Southern Rhodesia apparently the limiting minimum temperature at which *gambiae* breeds is about 51°F. (35), which is consonant with the conditions in the Transvaal.

The other malaria vector, *A. funestus*, breeds in running water, and is therefore more difficult to combat. De Meillon finds that in the Transvaal *funestus* requires a mean monthly temperature of 61°F. or over, a range of temperature between the mean maximum of the hottest month and the mean minimum of the coldest month of less than 40°F., and an annual rainfall of 30 inches or over (34). It is not surprising, in the light of these facts, that both *A. funestus* and *A. gambiae* are widespread in Africa, and that malaria is absent only in three types of region: the very dry regions; the plateau surfaces of over about 5,000 feet in the tropics and in the southern portion of the Union. As to the effects of malaria upon the health and well-being of settlers, varied reports are given. As the "disease that kills more than any other single disease in the whole world" (36), however, it cannot be dismissed lightly as of little consequence in the peopling of the continent. Measures taken

to combat the disease are doubtless frequently successful, and a certain immunity is sometimes acquired, especially by the native people. In Europeans an acquired immunity is, however, a dangerous thing since it is generally followed by blackwater fever (37). Natives, however, whilst suffering from malaria intensely in childhood, often acquire a partial or complete immunity in adult life, and the absence of blackwater fever in Natives appears to be a racial immunity acquired probably through many centuries of life in malarial regions. The effects of malaria on the native peoples is, however, serious enough. Schweitzer writes of the havoc wrought by the disease on native children in Equatorial Africa, and observes that " the negro who has malaria is a poor, broken-down creature who is always tired and constantly plagued with headache, and finds even light work a heavy task " (38). Schapera reports similar effects among the Bakxatla of Bechuanaland (39), and it is stated that more than half of the children of Southern Rhodesia have had malaria (40). In the " Poor White " Commission's investigations, however, the effects of malaria on the children on the Transvaal low veld appear to have been masked by the more serious results of malnutrition and by the winter season, perhaps, during which the investigations were undertaken (41).

One of the very serious effects of malaria is that it causes a " vast number of abortions and deaths of the foetus before labour in European women, for which, however, quinine has been found to be a successful treatment" (42). It is not known to what extent native women are affected in this way: one medical missionary has expressed to me the opinion, based on many years of experience in tropical Africa, that they are scarcely affected in this way at all.

Malaria, however, is an eradicable disease, and reports of improvement in health conditions come from many malarial regions of the continent. Its elimination from the Rongai Valley, in Kenya, by the drainage of the land and by cultivation, has recently been reported (43), but, of course, with our present resources, the difficulty of eradicating the disease from the neighbourhood of rivers and lakes is almost insuperable.

Yellow fever, carried by Aëdine mosquitoes, is now limited to the Upper Guinea coast, for, in spite of its being shown on several maps as endemic along the Lower Guinea coastal area, the report of the French administration is quite definite that it has not made its appearance there, although it is reported at Boma and Matadi in the Congo estuary (44).

More serious than yellow fever, because more widely distributed, sleeping sickness in human beings and nagana in animals, the two African forms of Trypanosomiasis, vie with malaria as the arch-enemies of human settlement in Africa. The trypanosomes are carried, of course, by the tsetse fly, of which more than 21 species have been found in the continent (45).

Human trypanosomiasis is caused by *T. gambiensc* and *T. rhodesiense;* nagana by *T. brucei*, *T. congolense* and *T. vivax* (46). The area infested with the flies is shown in Swynnerton's map, and the distribution of sleeping sickness is given by Reichenow in Zumpt's recent work (47). The two distributions are shown in Fig. 3.

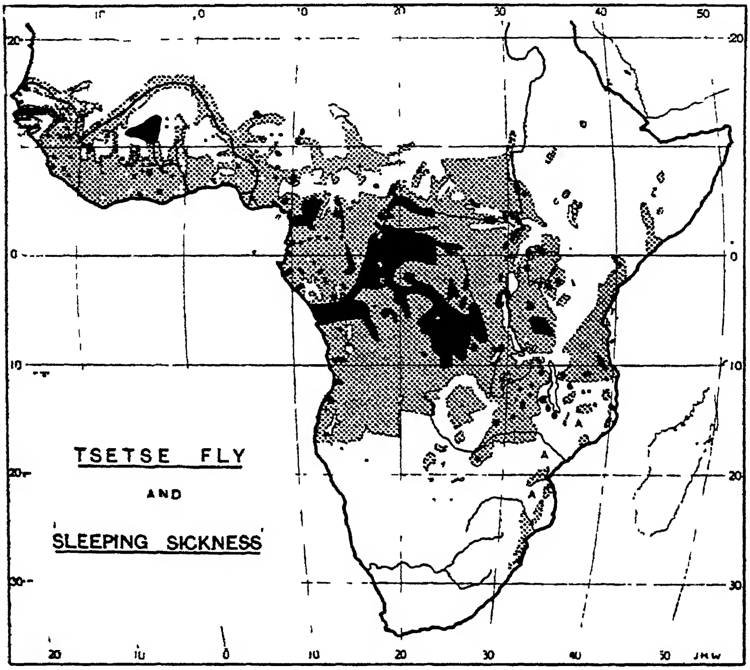

Fig. 3.

The Distribution of Tsetse Flies (stippled) and Sleeping Sickness (black), after Swynnerton and Reichenow. The parts of Portuguese East Africa marked " A " are noted in Swynnerton's map as " Much fly but information incomplete." Where sleeping sickness is shown apparently outside of the fly area, it should be assumed that the fly exists there.

Trypanosomiasis affects settlement in a twofold manner. In the first place sleeping sickness has been, and still is, responsible for the decimation of whole sections of the population in regions where its incidence is severe. The havoc wrought by the disease, for example, in Uganda, between 1898 and 1906, is well known. It was responsible then for over 200,000 deaths in Buganda and Busoga (48); between 1905 and 1918 there were over 30,000 deaths from the disease in Uganda, and in 1902 more than 19,000 out of the total population of 44,000 were wiped out in the Bovuma Islands. Schilling (49) estimates that 40 per cent. of the population of the Cameroons is affected, and in French Equatorial

Africa an examination of 787,000 natives in 1926 showed that 29,323 had the disease in a more or less advanced form (44).

In the Congo the disease appears to be even more widespread, and an experienced missionary, Père le Grand, estimates that eight- or nine-tenths of the native population of the Middle Congo has been destroyed by it (50, II., p. 574).

It is also unfortunately true of sleeping sickness that it is responsible for a high involuntary abortion rate among native women, the proportion in the Lower Congo being 7 per cent. for families where there is no trypanosomiasis and 24·5 per cent. where there is (50). Probably this one of the main factors for the low population density in some of the tropical regions.

In an indirect way, too, trypanisomiasis has put many obstacles in the way of settlement. By the high incidence of nagana many areas have been made uninhabitable by pastoral groups, unless they change their habits and adopt cultivation of the soil as their means of livelihood: a repugnant change to the Bantu. In this way, however, clearings in the bush can be made and the natural habitat of the fly is thus destroyed. Although this is generally successful as a means of survival, the agriculture is handicapped by lack of dung for manure, and by the difficulty of transport because of the absence of oxen.

The present position with regard to both forms of trypanosomiasis in Africa is very serious. Swynnerton states that some four and a half million square miles (out of a total of about eleven and a half million) is under infestation by the fly: "That in the greater parts of the areas under infestation cattle cannot be kept, and that in a vast proportion of them sleeping sickness still takes its toll of the human population despite the high efficacy of modern drugs and a huge expenditure on staff organisation, treatment and segregation in the various countries concerned" (45).

In the Report of the East African Commission of 1925 the same sad fact emerges: "All over Uganda, Tanganyika, Northern Rhodesia, and Nyasaland fly areas are increasing, and are having a serious retarding effect upon the economic development of these territories" (51).

But the cloud has a silver lining. Progress is being made in the discovery of prophylactic measures and several drugs are now being used with good effect. Of these "Bayer 205" (Germanin), "309" (Fourneau), Atoxyl and Tryparsamide are all having a measure of success in the treatment of sleeping sickness. Nagana can be prevented for short periods by the injection of Tartar Emetic: a useful prevention when using animal transport through fly belts, but of no permanent value.

Recently a German investigator, Claus Schilling, has had promising results with the inoculation of animals in Tanganyika, eight out of the eleven animals inoculated remaining immune to

nagana (49). This seems to be a step forward, and the results of the tests on a larger number of animals is eagerly awaited.

Another hopeful sign, so far as the eradication of *G. palpalis* is concerned, is the successful clearing of the fly along river banks by the "Block" method. This method, however, is only applicable to *palpalis* and other riverine varieties (49a).

In comparison with malaria and trypanosomiasis the other tropical diseases, though serious, are of minor importance in considering possibilities of increasing the population of the continent. Amoebic dysentery will probably disappear with the improvement in sanitary and hygienic methods of living. Hookworm, yaws, filariasis, smallpox, syphilis, can all be vanquished in time. But "always something new out of Africa" is true here, too, for in Angola spirillum, or relapsing, fever is carried by a tick-like insect which, unlike most fever vectors, is found in Angola only on the uplands at altitudes above 2,000 feet (52).

The Land Question.

Another geographical aspect of the settlement of the continent is the productive capacity of the land and its availability for colonisation. It is impossible in an address of this kind to consider all parts of the continent: that has been attempted elsewhere in some detail (53). It will perhaps be of more value to examine what is known of the conditions of the more unsettled parts of the continent in order to see the nature of the problem confronting European colonists and administrators. Perhaps the area most typical of the conditions in Central Africa is Northern Rhodesia, which has often been referred to as a country "practically unoccupied" and having vast potentialities for settlement.

In Northern Rhodesia there are approximately 1·37 million Natives and about 10,000 Europeans (54). The total area of the Colony is 288,400 square miles, or approximately 186 m.a. (million acres). The Natives occupy reserves having a total area of 72 m.a., of which 37 m.a. comprise Barotseland and 35 m.a. are in scattered areas (Fig. 4).

The European areas total 8·8 m.a., of which 6·2 m.a. belong to the North Charterland Company (S.W. of Fort Jameson) and the British South Africa Company (Tanganyika Estates), deducting the native areas included in these concessions. The remaining 2·6 m.a. of the "European land" is sold or leased to form 982 holdings, of which 576 are larger than 1,000 acres. This farm land is shown in Fig. 4.

A recent Government investigation of the character of this farm land has brought to light some interesting facts (55). In the southern portion (marked "A" on the map) from Zimba to Tara, the land is considered to be of the ranching type. The grasses are plentiful, but coarse and sour. It is estimated that 20 acres are necessary for one beast, and the poverty of the pasture necessitates the use of low-grade cattle; highly bred bulls are not

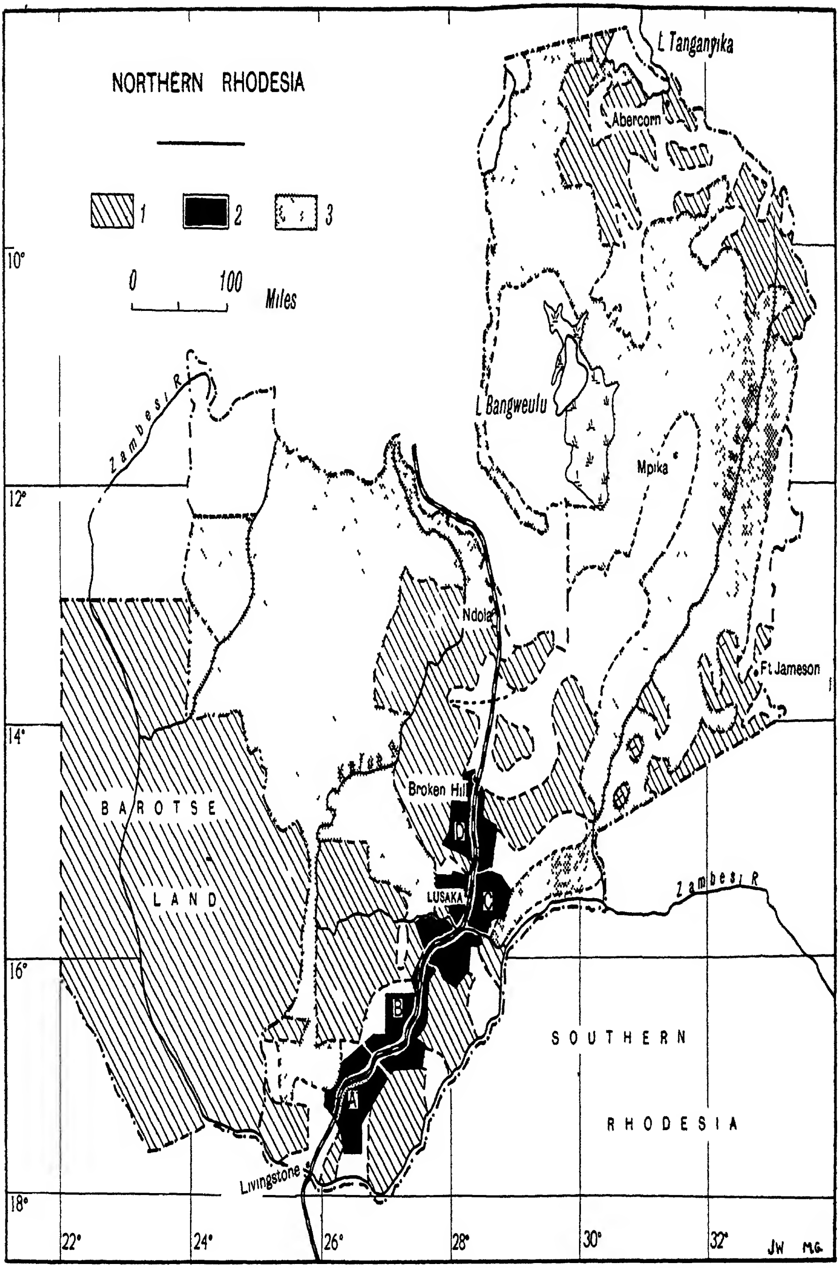

Fig. 4.

Northern Rhodesia, showing 1. Native Reserves, 2. European farmlands, 3, Tsetse Fly infested areas (outside the Native Reserves).

To face Page 50.

recommended for this area. The ground suitable for crops occurs only in small patches. The soils are "poor, hungry, and incapable of producing large quantities of sweet grass except in small patches for short periods" (55, p. 4). It is stated that ranches of not less than 10,000 acres are necessary under existing conditions, and the Commission recommends that water should be found before any farm is sold to settlers.

In area "B," from Tara to Magoye, the land is considered to be most suited to cattle farming, but small parts of it are suitable for the cultivation of mealies, tobacco, kaffir-corn, ground nuts, and various rough cattle food. Large areas in this sector, however, are found to be unsuitable for European settlement on account of the poorness of the soil, the lack of surface water, the low nutritive value of the grass, the expense of clearing the dense bush, and the scarcity of patches of soil suitable for cultivation.

The Commission recommends that this type of ground "could be best used by natives, because their requirements of land . . . are very small compared with those of the European settler" (55, p. 182). Other recommendations include the formation of group settlements, in which each farmer should have enough capital to enable him to become an immediate earner of revenue. It is also pointed out that it is necessary for settlers to send their children to the coast for holidays.

Section "C," from Magoye to Lusaka, is similar in character to "B," but a few farms could be improved to carry mutton (not wool) sheep. The areas to the north of the Kafue River and to the east of the railway line are considered unsuitable for European settlement, on account of the ruggedness of the ground and the thinness of the soil. The possibility of afforestation in this zone is urged by the investigators.

In the fourth section, "D," from Lusaka to Broken Hill, there is a great diversity of soil, which varies from "light white and light brown, poor, hungry, sandy soil," based on clay, to the loams of the Chisambu maize belt and the sandy loams of the northern part of the section. This is an area where mixed farming is possible, but the northern part of the area, around Broken Hill, is handicapped by the presence of tsetse fly, which "constitutes a serious disability to farmers desirous of moving their live stock through or from the area (55, p. 184). It is pointed out that the fly danger can be considerably reduced by clearing the bush, but the process is expensive.

In addition to stating these facts the Commission makes some important recommendations with regard to the control of settlement. It is recognised that over-production in relation to inland markets must be guarded against; that for ranching at least 1,000 head of stock are necessary, involving a capital of not less than £3,700.

The caution regarding over-production is a significant one, for the position has been examined with some care in the Colony

(56). With a self-supporting native population and a small European community, a surplus of grain is easily produced. To avoid exporting at a loss it has been recommended, for example, that the 40,000 acres sown to maize in the European farming belt in 1935 should be reduced to 37,000 acres. Of the total area of 2·46 m.a. farmed by Europeans in 1935, 70,000 acres were cultivated, so that 97 per cent. of the land in the farming areas is at present used for grazing.

Beyond 30 miles from the railway it is not profitable to produce crops of low value, and the efforts of the colonists in these remoter areas have been directed to the production of coffee, cotton and tobacco. Coffee has been tried in the Abercorn district, where the soils require heavy manuring, and the white stem borer (*Anthores leuconotus*) has been a serious pest. In 1935 there were 550 acres planted to coffee in this district, but I am informed (57) that the estates are being deserted.

Cotton is being experimented with, but in this enterprise the high variability of the rainfall and the ravages of pests have been almost too great handicaps for the industry. Of the pests the American bollworm (*Chlorida obsoleta*) and the spiney bollworm (*Earias insulama*) have been the most troublesome, and the "U4" strains of cotton, bred at Barberton in the Transvaal, which have proved successful in Nyasaland, failed to give significant results in the railway farming belt of Northern Rhodesia. It has been found that one of the two most troublesome stainers, *Dysdercus superstitiosus*, uses the cotton plant as a host between the early and late stages, when it uses the wild hosts of the savanna.

So far as tobacco is concerned, good leaf is being produced in the Fort Jameson and other districts, but the markets are limited and exacting, and only the finest leaf can now be exported.

Another factor to be reckoned with in considering the settlement of Northern Rhodesia is the presence of the tsetse fly. *Glossina palpalis* is found in the extreme north of the Colony, near Lake Tanganyika, and *G. morsitans* infests nearly two-thirds of the country. Both of these varieties carry the trypanosomes of sleeping sickness and nagana. Native cattle—of which there are only 351,000 for over a million natives outside of Barotseland—are limited to fly-free areas (58). Any extension of the European settlement would, as we have seen, be based on pastoral farming, which could only be carried out in fly-free areas. A reasonable estimate of the fly-infested areas not included in the native reserves or in the areas already occupied by European settlers is about 29 m.a. (53, pp. 265-6).

Finally we must recognise that some parts of Northern Rhodesia are unsuitable for European occupation on account of their low altitude, and consequently their high temperatures and endemic malaria. The greater part of the Loangwa Valley falls in this category, as well as considerable non-native areas in the Zambesi Valley, below Livingstone.

Bangweulu Lake and swamp form excellent fishing grounds and good manioc lands, but they are not suitable areas for European settlement. These low-lying lands and swamps constitute together an area of about 12 or 13 m.a., although it will, of course, be understood that they form possible areas for supplementing the existing native reserves.

We can now perhaps get some idea of the availability of new land for settlement in this almost empty country. A statement of the position can be tabulated somewhat as follows:—

	Million Acres.
Total area	185·81
Barotseland Reserve	36·82
Other Native Reserves	34·71
Forest, Game and Archaeological Reserves	5·01
Companies' Concessions (less native areas)	6·25
Alienated to European settlers	2·58
Townships	0·12
Total reserved or alienated	85·49
Land unalienated	100·32
Lowlands, swamps, etc.	13·00
Fly infested (outside of Native Reserves)	29·00
Available for occupation	58·32

From this area a deduction would have to be made for rough ground, lack of water, malarious valleys and other conditions, which would leave, perhaps, at most, 50 million acres available for new settlement. Under present conditions this would be ranch land, and, estimating 10,000 acres as the minimum for each ranch the total available land would provide about 5,000 holdings.

Meanwhile the native population is said to be increasing, and some of the missionaries think that it may be doubled in 25 to 30 years (50). There will be more land needed for their development. A wise administration will avoid the difficulty that we in the Union are having to cope with in finding new land for a growing native population.

The Sources of New Population.

We have now to consider briefly the ways in which an increase in the population on the continent can come about, presuming that an increase is possible and desirable in at least some parts of the continent.

When we examine the possibilities of large numbers of Europeans coming as colonists to Africa, the facts of the situation in Europe itself are from all points of view disquieting. The greater part of Europe, and particularly North-Western Europe, has entered a period during which the population reproduction rate is showing a definite and rapid decline. In Western and Northern Europe the net reproduction rate—i.e., the number of future mothers born to a mother now—was 1·3 fifty years ago. In 1933 it had fallen to 0·76 (59, p. 44). In England the rate in 1933 was 0·75; in Germany in 1934-6 it was 0·9 (60); in Italy between 1·0 and 1·2. Only in Russia is the European reproduction rate probably as high as it was fifty years ago: the population there seems to be increasing at about the rate of three millions a year.

After allowing for all other possible causes of the decline in fertility there is general agreement that the root cause is birth control.

Nor is this tendency limited to Europe and America. In Asia a similar trend in reproduction is observable in Japan, where "for more than a decade, probably for more than two decades, the fertility rate has been falling" (61, p. 102). It is now officially acknowledged in Japan that contraception is practised there, for in 1931 the Home Secretary is reported to have said that birth control was a personal affair, and that the Government would neither encourage nor discourage it (61, p. 110).

It is important to note that in the Union of South Africa the present trend is also "definitely and unmistakably towards a declining fertility" among the European population (62). Apart from other causes the present tendencies for population to concentrate in large urban centres is apparently a factor in the present situation (63), for rural fertility rates are in general higher than those of large cities (64). In South Africa this trend is also apparent (65).

But whatever the causes of the declining fertility may be the effects on the prospects of colonisation are unmistakable. Since 1929 the emigrants from Britain to the rest of the Empire have been fewer than immigrants in the opposite direction. The situation has changed, and the prospects of good employment in Britain at the present time are more attractive to most workers than the hazard of developing land of doubtful potentiality on the fringes of civilisation. For the opportunities of the last century have gone for ever: the great expanses of good and profitable land have been occupied; the pioneer zones now almost everywhere are of doubtful potentiality.

Even the love of adventure may be extinguished by the prospects of droughts, malaria and the constant struggle against an adverse climate. There is no great exodus from Europe to-day, and even Canada, with its invigorating environment, has been attracting fewer and fewer immigrants in recent years (66, p. 62).

In the great over-populated countries of Eastern Asia some significant trends are discernible. According to Chen Han-seng there is a general tendency for Chinese emigration to diminish (66, p. 150). In Malaya Chinese labourers are being replaced by Europeans and Indians, and in Sumatra their number has steadily diminished in recent years. In the French Sudan and in French Equatorial Africa imported Chinese labour has proved a failure; in Java the Chinese, who were the original pioneers in the Dutch mines, are being steadily replaced by Javanese.

In Japan the case is different. In a country where more than two-thirds of the entire area under cultivation is held by farmers cultivating less than 2·45 acres each, the Japanese have become past-masters in the science of cultivation. In 1936, according to Pelzer, there were 2,970 persons in Japan to one square mile of cultivated land (66, p. 155), and the country now seems to have reached its maximum population. In Hawaii, and more recently in Brazil, and in the Pacific Mandate Japanese settlers have proved beyond a doubt their ability to colonise the tropics on a basis of peasant labour. There is no other colonising power that has shown a comparable ability. It is stated by Uyetsuka, that the Japanese colony in the Amazon basin is healthy, flourishing and prosperous (67), but the final success of this most difficult colonising enterprise is perhaps still to be proved. And yet, in spite of this remarkable adaptation to tropical conditions there are not yet quite a million Japanese residing in foreign countries, and it is recognised in Japan that emigration has done very little indeed to alleviate the pressure of internal population. There is no gainsaying that political obstruction has been the main obstacle to Japanese colonisation.

But in tropical Africa the man who has prior claim to any possible expansion and development is the African native himself. What is his capacity to increase and develop?

The low density of the native population in most parts of tropical Africa is generally attributed to such factors as inter-tribal warfare, the various diseases of the tropics, the slave trade, famines, the high infant mortality and the low birth-rate. To these must be added the frequency of abortion, both involuntary (from sleeping sickness, for example) and induced (68, p. 156), the long suckling period customary with most African native mothers, and, in more recent times, the disastrous effect on tribal morality of the forced labour of large numbers of the men in various parts of the continent.

What the actual reproduction rate is, is not known with any degree of exactness, but the indications seem to point to rates not very different from those in Western Europe to-day. In parts of Tanganyika Fischer reports an average birth-rate per woman of 2·9, of which 1·5 die as infants (69). The general native census for Tanganyika in 1921 shows approximately the same rate for the whole native community.

In the Western Sudan Labouret gives a rate of 318 per 100 women among the Lobi (70), and in the Congo Ryckmans reports rates of 2·45 and 3·80 per woman (71). One may compare these rates with the average of 1·67 per married woman in Germany in 1933 (59, p. 57).

The survival rate in African communities, is, however, low, due partly to injurious methods of feeding babies even during the suckling period (68, p. 187), as well as to poverty and insanitary conditions. Ryckmans, however, reports a high survival rate among the Christian community of Madimbe in the Congo, and there is no doubt that in native communities served by medical missions, the improvement in hygienic standards is having a beneficial effect upon infant health.

At the present birth and survival rates, however, there cannot be a rapid increase of the native population. According to one authority it is impossible to say on the whole whether the native population south of the Sahara is increasing or decreasing. "It is probably not decreasing; it may very likely be about stationary; it is not impossible that it may be increasing, but if so, the rate of increase is certainly slow" (72).

Finally we may ask, what are the factors which will make for a desirable increase in the native population and an improvement in its well-being? Certainly a better infant mortality rate is possible with European hygienic methods. Our own native locations in the Union are on the whole anything but good examples of such progress. but there are sure signs of an awakening of the public conscience in this respect.

In methods of cultivation, in stock-breeding, and so in food supplies great improvements are possible. One of the great problems in Africa is the supply of proper nourishment. The disastrous effects of under-nourishment are particularly clear in the equatorial regions, where probably the climate is fundamentally responsible for the lack of proper cultivation and the appallingly low standard of native physique. Recent investigations, too, have brought out the far-reaching effects of diet upon neighbouring tribes on the East African Highlands (73). The European communities have a great part to play in native development along these lines.

There is undoubtedly the prospect of increase in numbers and improvement in health and well-being if the natives adopt the best moral standards of European civilisation. Unfortunately there is also the inevitable risk that they will adopt the worst of our standards, to their immense detriment. The white colonies in the continent, and particularly we in the Union, have an unescapable responsibility here. The supreme folly and wrong, as I see it, would be to grasp a region for which, as white people, we may not be suited, and to withhold from the African the best features of our civilisation in order to prevent him from developing as rapidly as possible.

On the other hand the great opportunity for us Europeans in the Union is to train and send out Africans who, equipped with the finest products of our civilisation, will be able to co-operate in the task of making this continent a fit home for those who will eventually prove to be best suited to the African environment.

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TRANSPIRATION AND WATER SUPPLY OF SOUTH AFRICAN PLANTS

BY

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Presidential Address to Section C, delivered 6 July, 1937.

In the last eight years South Africa has seen a considerable change in the amount of rainfall during the different seasons. During one year more than half a yearly average rainfall would occur in one month, preceded by eleven months of drought, whilst in other seasons it was regularly average. This fact implies that the rainfall itself is not decreased, on the contrary, meteorological stations with records extending only over about 10 years show decidedly an increased average for the last few years. It may, however, be asked whether this erratic fall of rain with prolonged drought does not affect plant life to any extent. Plant life is so utterly dependent on rain, at least in the semi arid portion of South Africa. I do not include the crop plants; we all know that too little or too much rain may spoil a wheat or mealie crop, but I refer to the indigenous plants—to our natural veld.

Having observed the ravages of the drought in 1933, then the effects of the flood in 1934 in the broken veld at Fauresmith, I had to come to the conclusion that the influence was very visible. The drought killed about 30-40 per cent. of our bushes, and before bush seeds had time to germinate in the ensuing flood, undesirable Steekgras took in the bare spaces, together with *Chloris virgata*, both of which from the point of view of feed for the animal are of very little value. Three years have passed, and although the Steekgras has decreased considerably the district of Fauresmith has certainly changed in character, at least 20 per cent. more grasses are on many farms, except the brak veld, and it certainly will be so, as long as we have the heavy rains in midsummer.

The last remark implies that the conditions for the growth of bushes and grass are different, not only growth, but also germination and probably other physiological processes. The Karroo bushes germinate and grow at lower temperatures than the grasses; they never grow as quickly as annual grasses do. And for the rest? Why is it that in drought years grass disappears from the broken veld long before a bush is damaged? The cause lies primarily in the different water requirements of bush and grass. What do we know about it? Travelling through South Africa we all know that the forest areas in the south-east are rather moist, that the country of the Karroo shrubs is considered

dry or at least semi arid, and the grass veld has on the whole a higher rainfall than the Karroo area. The type of vegetation is mainly caused by the rainfall. *A priori* is seems feasible that large plants like trees would need more water than grass swards or tufts, and these, if they are juicy, again more than the hard-leaved Karroo shrubs or desert grasses. Whether this assumption is right careful investigations have to show.

Each plant, to get hold of the necessary minerals to build up its body, has to take up a dilute solution from the soil. If the soil is poor in soluble vital salts, more water has generally to be taken up by the plant to get its minimum of vital salts; the plant does not attempt to take in more than is absolutely necessary if it is difficult to get it at all. It is amazing with what low quantities of mineral salts certain plants, especially grasses, can live, at any rate vegetatively; only when it comes to reproduction, then the trouble begins. The layman, even the farmer, does not see anything unusual in the plant which, for instance, has taken up only a third of the phosphorus which a more fortunate specimen of the same species contains. Very often the plant looks beautifully green, but when the whole veld consists of such plants and cattle graze on the veld the farmer may find that something is amiss; this applies especially to grasses. Poor grasses may not necessarily grow on a soil with a low rainfall. On the contrary, a poor soil saturated with water which the plant takes up very quickly during a period of extensive growth may produce an apparently good crop of green grass which consists, however, of large amounts of water and very little dry matter and minerals. Even on such a soil the water retaining capacity of the plant is limited, the fresh matter containing up to 85 per cent. water and 15 per cent. dry matter. The water subsequently taken up has to be disposed of in the same way as on a soil where grasses contain only 50 per cent. or less of water and the rest of dry matter, disposed of by transpiration, that is to say, by the loss of water through the stomata and to a small extent also through the epidermis of the leaves. To build up dry matter each plant species needs a large quantity of water. For crop plants such figures have been ascertained even in South Africa. For 1 kg. dry matter of maize 270-380 kg. water are needed; for wheat 580 kg. under the climatic conditions of the Agricultural School, Grootfontein, Cape.* For veld plants such figures are not yet available, but provision is made to get some in the near future. It can be foretold that they will be smaller, as the plants could not grow under our climatic conditions without irrigation. The rainfall would not be sufficient to provide the necessary water. One of the reasons, if not the only one, why plants in arid and semi-arid areas are tufted and never form a

* Water Requirements of Different Crops.—To get 1 lb. dry matter, so many lbs. of water are required: Maize, 270-380; Lucerne, 810-900; Potatoes, 255; Wheat, 563-582; Oats, 590-676; Peas, 606-651; Beans, 607-651. Published by Bosman, 1936.

close association is the amount of water present; the less water present per soil unit the more soil the plant, *ceteris paribus*, requires to drain to obtain the necessary water. If a poor soil under a high rainfall is however manured or fertilized, the tufted grass veld may change over into a nearly closed sward, but unfortunately we cannot fertilize under low rainfall as the chemicals would burn the plant roots. But the lesson is quite clear. If the minerals are more concentrated, then the plant does not need such large amounts of water to dissolve it. The water requirement is smaller and the plants can grow nearer together.

Until about 20 years ago the view of the famous plant ecologist, Schimper, was accepted, viz., that plants of a dry habitat, the so-called xerophytes, need less water for their life than mesophytes or shade plants. The various devices against transpiration of such xerophytes were enumerated, e.g., thickened epidermis with sunk stomata, thick layers of cuticle, woolly hairs, succulent structure, etc. Then the Russian school of physiologists put forward the theory that these so-called xerophytes displayed a high transpiration power, much higher than the mesophytes, in other words, that they were by no means economic with water. As with all new theories, this one was regarded with reserve, and quite rightly, too. Although the Russians published many data, the problem was investigated especially by German scientists, and South Africa also made its contribution. A large number of figures collected in the tropical forest, in the steppe, the salt marshes or in the Artic regions have been published, and—with the exception of succulents—bear out the Russian idea in certain circumstances. The first condition is plenty of available water. There is no doubt that xerophytic plants cultivated under laboratory conditions and supplied with enough water to get well established, display a large transpiration power. Only very rarely in nature do xerophytes transpire large amounts, when the soil is soaked with water, but xerophytes, our South African veld flora of the semi-arid region, exhibit this phenomenon very seldom. Perhaps the changed method of measuring transpiration has also something to do with the observed results. Up to ten years ago the procedure laid down was to measure whole potted plants. A potted plant has necessarily less soil from which to draw water than has the plant in free nature, the soil has therefore to be kept at a higher water content to avoid the wilting of the plant. The new torsion balance, a German product, which allows of weighing leaves or small twigs in fractions of minutes for plants with high transpiration power, and minutes for those with lower transpiration power, has done away with pots, etc. The twig from the living plant is rushed to the balance and weighed before (humanly speaking) it has the chance to realise its disconnection from the mother plant and it reacts by closing the stomata or folding the leaves or just diminishing transpiration. All those reactions take place in a few, probably about five, minutes, and

in the interval the actual transpiration as it would have occurred on the mother plant is maintained and can be measured. If the leaf or twig is left for any length of time on the torsion balance, then the same mistakes creep in as in the early experiments with cut branches, viz., diminished transpiration, closing of stomata, wilting, etc. It is, therefore, possible to ascertain within a short time the actual transpiration of the plant under any conditions.

It could thus be shown that Karroo plants on rare occasions after heavy rains display a large transpiration power, but as soon as the soil begins to dry out the transpiration sinks a lot and is very small in a soil with a 5 per cent. moisture content. Here it may be stated that most of our South African soils are about saturated with a 24 per cent. moisture content, though one frequently sees in the literature figures of 60-70 per cent. moisture; these are not natural soils, but rather denaturated, pressed under laboratory conditions and give a misleading picture. Soil of the same texture as our South African sandy loams investigated at Rothamsted, England, shows the same water capacity. In this respect the soil of the South African veld is theoretically not worse off than the English soil, only this 24 per cent. moisture content is seldom met with in a South African soil. If the soil moisture sinks still more no transpiration of Karroo plants is noted within the few minutes of observation. Even if continuous experiments in pots are done during the dry winter months the transpiration of a Skaapbos or a Vaalkaro may be nearly zero, although the actual day time temperature and sun should allow of a good water loss. If the daily transpiration curve of a Karroo bush is examined closely, we see that from the night where it is practically nil, it rises sharply at sunrise and with some fluctuation, as if it had overshot the mark, increases with increasing light and temperature for a few hours, then a drop occurs, often over noon, in high summer even earlier. This drop may last from 1-3 hours, then the transpiration rises again, often reaching its maximum for the day only in the afternoon at 4-5 p.m., and decreasing later slowly or quickly according to the prevailing light conditions. Very seldom under the climatic conditions of Fauresmith is a transpiration curve with one maximum obtained, although some hundreds of determinations have been made over a considerable period. The probable reasons for this curve will be discussed later; the main point for the moment is that the same curve occurs summer and winter, as long as perceptible transpiration actually takes place in the cold season.

Similarly, if grasses are investigated in the semi-arid region of Bechuanaland, from sunrise onward their transpiration increases with increasing light and temperature for a few hours. Then the transpiration drops and with some fluctuations may rise to a second maximum in the late afternoon. Trees on the dry shaly kopjes of the Transvaal show a similar daily course of transpiration. If, however, Rooigras (*Themeda*)—one of the

species which has been under observation in Bechuanaland—is investigated at Pretoria, Miss Mes finds that in most cases the transpiration follows the increasing light, temperature and decreasing air humidity, the one difference being that the maxima and minimum of the meteorological factors occurred considerably earlier in the day than at other places where similar investigations have been done; from noon on the transpiration of Rooigras again decreases with decreasing temperature and light and increasing air moisture. Such corresponding curves are rare, the more so as the apertures of the stomata which follow the meteorological factors to a large extent, and have therefore a checking influence on the transpiration, drag behind not only for minutes but sometimes for more than an hour. When the literature on transpiration for plants in dry areas is looked through, whether in Europe or in the Namib, reference is always made to the depression of transpiration at noon. South Africa offers perhaps the most data (although unpublished), because its flora has been systematically investigated for economic reasons.

Some twenty-five years ago in America relative transpiration was investigated, that is to say, it was not the actual amount of water lost that was determined, but the time which a leaf under certain conditions took to discolour a blue sheet of filter paper soaked for a specific time in a 3 per cent. cobaltous chloride solution. The value was compared with a standard water surface. The precautions to be taken to get reliable data were unfortunately so many that the method never became very popular or got beyond the qualitative test stage in other countries. Handled by its author, Livingstone, and his school, interesting results were obtained, of which, however, only the occurrence of permanent and temporary wilting as well as incipient drying concern us here. By temporary wilting we understand the phenomenon of a plant wilting, presumably in the hottest part of the day, but when put into a moist atmosphere for 24 hours, recovers enough water from the soil to show no external signs of a water deficit in its leaves. Permanent wilting of a plant cannot be remedied by putting the plant into a moist atmosphere, it generally leads to the slow drying off of the plant. Incipient drying is, so to say, the precursor of temporary wilting. Externally nothing can be seen from the leaves of the plant, no drooping or flabbiness, and when careful studies are made on the water content of the leaves, it is found that since sunrise the water content has decreased, sometimes by 20-40 per cent. Now we come to the point, if European plants or a number of our large leaved garden plants show signs of wilting, and if their water content in the fresh state early in the morning and at the time of wilting are compared, the amazing fact is found that a loss of 2-3 per cent. of the water causes the plant to wilt. If this should be the case for our veld plants in South Africa, I am afraid we (except the early riser) would never see a fresh green plant. Our South African plants do not show

signs of wilting for such trifling losses; true enough, grass leaves fold up or roll, if the loss is about 20 per cent. and more, but our bushes just stay as they are. They may loose their green colour and get the grey-green tint of the Karroo, but drooping—no. And yet something is different, must be different. Although the water content of the leaves on ordinary summer days has not decreased as much as with grasses, it has decreased, and the Karroo bush shows the so-called incipient drying. Contrary to the grasses, the Karroo bush tries to check the excessive transpiration; even if only for a time, it lowers its water output considerably, but not in all cases could a narrowing of the stomatal aperture be noticed. That is an important point, although it is known that the movement of the cells may drag behind; it is most likely that the Karroo bush has some other interior means of checking loss of water. The viscosity of the plasma may be greater, the constitutional water perhaps not so easily lost, the osmotic value may be higher, holding back more water, or other forces like drought resistance help, at any rate the transpiration is checked during the hottest part of the day. Apparently there is some process in the plant itself which checks the loss of water. It is important that the stomata should not all immediately close, as this would naturally interrupt photosynthesis, the building up of organic material. If the plant has another means of checking its water loss, so much the better. It generally occurs after a very high transpiration value has been reached; but after an hour or two of smaller values a renewed strong transpiration sets in, often to be checked again. There is no doubt that there is a shortage of water in the leaves at the time of decrease, and that the transpiration stream, as the water flow from the roots to the leaves is called, does not supply quickly enough sufficient to maintain a constant water content, the dry matter increasing as a percentage of the fresh matter. It is clear that not all Karroo bushes transpire at the same rate. I do not want to bother you with names which convey no meaning, only a well known plant may be mentioned, " Old Man Salt " and the related family, contain plenty of salt and grow mostly on brak, and are therefore called halophytes. They are the plants which transpire about the least of the non-succulent type. The succulents themselves, of course, show exceedingly small transpiration rates.

Comparing the different transpiration curves for grasses and Karroo bush, the main difference seems to be that grasses, even if they show signs of drooping, continue with a large water loss, whilst Karroo bushes check the loss much more efficiently. Badly wilted grass often disposes of in one hour far more water than its own weight. Even nearly dry grass still allows water to go off.

We have seen in the foregoing that the Karroo bushes, succulents, halophytes, shrubs and trees do not squander water so undiscriminately as, for instance, grasses. They do not transpire

with full force and capacity. Even if well supplied with water they generally decrease their loss during the hottest part of the day. In droughts they transpire only for a few hours a day. It is natural that this leads to a smaller average transpiration figure than that for grasses. It has been mentioned that the water loss of any leaf can in an hour far exceed its water content. Generally the water loss is calculated on fresh matter and surface, but on the whole the transpiration calculated on fresh matter per hour gives the best impression, also to the layman, of what amounts of water are really removed from the soil by transpiring plants. The smallest transpiration is, of course, 0 or near 0, and happens in the dark of night for grass and bush. For grass we may in the rainy season even record a negative value, that invisible moisture settles on the fine papillae. Karroo bush peculiarly enough often shows a small amount of transpiration on moonlit nights. So much for the minimal values. What about average hourly and maximal hourly values and average daily outputs? For 1 lb. of grass an hourly value in full sunlight of 2 lbs. of water is common, the highest value recorded so far has been 6 lbs., but afterwards the grass wilted. The highest daily value so far recorded was 15 lbs., but this value belonging to the same series as the highest hourly value is quite exceptional, although daily water outputs of 10 lbs. per 1 lb. of green grass leaves are common; the average summer daily output being between 7-8 lbs.

It was mentioned above that the exact water requirements of Karroo plants are not yet known. But an approximate figure can easily be calculated from the available data. The space of soil which produces 1 kg. of dry matter (not fresh matter) of Karroo bush, which has in good conditions a water content of 60 per cent., receives under our rainfall 358 kg. of water, which is certainly not all used by transpiration. We know, to our regret, that much of the water runs off and evaporates, which brings the figure immediately below the water requirements of maize. Considering that the water requirement of lucerne is about three times as high as that of maize, it is of interest to note that on the few occasions where the transpiration of lucerne was compared with that of Karroo plants, the water loss for the lucerne was at least four times as high.

The transpiration of Karroo bushes is much smaller, although some of them may show occasional high hourly values on sunny, hot days. One pound weight of Karroo bush leaves loses on the average 3-4 lbs. water daily, and in exceptional cases up to 5 and 6 lbs. An hourly maximal output of 2 lbs. is rare; generally it is about 0·5 lb. to 1·4 lb. It is understood that the quoted values are maximal values in early summer. Towards the end of the season the transpiration values for grass and Karroo bushes are much smaller, thus in the calculation of, for instance, yearly water output, a problem which always presents great difficulties, much smaller values have to be taken as average. For Karroo

bush 2 lbs. water per lb. leaves per day seems to be the average value. The seasonal decrease of the transpiration regardless of temperature is interesting to note as the stomata are *not* responsible for it. On the contrary, it has been noted time and again by Miss Mes and myself that at the end of the season the stomata remain open, that is to say, if they were the only regulating factor, their behaviour would tend to keep the transpiration constant. The contrary is true, the transpiration is diminished, and this shows clearly that there are other forces at work to govern the water loss.

The average water output for South African trees from dry habitats is still smaller than that of Karroo bushes. The hourly maximal value is only on rare occasions 1 lb. per lb. of leaves, although trees of moister habitats may easily overstep this value, and some introduced species of *Acacia*—Wattles—may reach the astounding figure, for a tree growing on dry soil of 1·7 lb. of water per lb. of leaves, generally it is 0·4-0·6 lbs. The daily average water loss per lb. of leaves in summer is seldom 2 kg., except for *Leguminosae*. Some foreign trees, however, may have a considerably higher water output, whilst conifers again scarcely lose more than lb. per lb. per day. South African trees of *wet* habitats may lose 6-8 lbs. of water per lb. of leaves, quite as much as average grasses; they do it, however, only when plenty of water is available.

It has been said that Karroo plants or trees on dry hills try to decrease the unavoidable transpiration over the hottest time of the day. Karroo plants in winter, in spite of favourable light and temperature conditions in day time, may restrict the water loss to the morning only, or in deep winter stop it altogether. There is certainly a tendency in plants of habitually dry habitats not to squander water in lean times. Grasses in Bechanualand on the contrary have unfortunately not that regulatory property, but continue to transpire, although their end of season transpiration is considerably lower than that during spring. It stands to reason that *ceteris paribus* the grasses use much more water than the small bushes per unit fresh matter. This transpiration of the grasses which leads daily to incipient drying, often to temporary or at times to permanent wilting, may be the crucial factor in the existence or disappearance of grasses in an area. If in rainy years in the broken veld we have grasses, it is not only that the grasses grow quicker than the bushes, that is only the first step, but there is enough water to supply the heavy needs of grasses. A drought year may still offer by an occasional shower the right condition for the germination of the grasses, but the water supply is too small to replace the constitutional water loss in the transpiration, permanent wilting soon sets in and the grasses die down and annuals disappear completely.

The rainfall has certainly a lot to do with our vegetation. In a high rainfall area at the coast the grass can form a sward

and is not tufted as in the interior of South Africa. Grasses generally have not deep roots, and depend entirely on the rainfall and not on the water level in the soil. Karroo bushes have, if the soil is deep enough, quite long roots, but do not reach the water level. Trees are different, they may reach the water level, and they certainly do so in deserts, one often sees in Namaqualand green trees bordering empty river beds which never have a drop of water for years. Although these trees are more or less in a dormant state, they survive because their roots reach the water level. If by any chance the water level should sink they would die. The transpiration of real desert trees has never been investigated in South Africa, but in America near the Grand Canyon it has. Although one can not often generalise in science, we take it that the American findings apply also to South Africa. Only single branches of the tree are really active, and very little too, through the drought periods, and are therefore similar to Karroo bush under extreme conditions. It is for that reason that trees with plenty of foliage can survive the adverse seasons. It must not be overlooked that although per unit surface of fresh matter the transpiration of a tree is often small, the units of fresh matter or leaf surface of a tree may be very great, and the dormant state of most of the branches is a very efficient means to cut down transpiration. Though the transpiration of trees is not so directly dependent on the rainfall, a tree cannot for ever tap the ground water, or remain dormant for ever, but at times this ground water needs replenishing and the tree needs some new material for respiration, that is to say, rain must fall to make up the water deficiency and the stomata must open for assimilation, and at the same time for very active transpiration, but rain is certainly needed. The tree growing in dry soil, but not in desert, has no such devices for keeping dormant for months or even years. It is quite true that in winter its transpiration is very small, and may in a dry climate become very active only in October, but most trees grow under higher rainfall, and the small transpiration will only take place in the actual winter months. These trees certainly drain the ground water for nine months out of the year, and, in spite of their relative small transpiration per unit weight or surface, the absolute amount per tree is great. It means that the ground water has to be replaced at frequent intervals. If ample or surplus rain falls, this takes place automatically. If, however, little rain falls, the water level may sink. It is quite clear that many trees, species of *Eucalyptus* for instance, do not send down deep roots, but the roots spread horizontally in the soil and drain this soil over a large radius. The water of the top layer of soil is certainly rainfall water which has to be replaced soon. In a large eucalyptus plantation the water removal by transpiration will be enormous, as the hanging leaves do not shade one another very much, and all the leaves receive sunlight, and have, *in toto*, not per unit of weight or surface, a large transpiration.

Average and maximal daily transpiration values have been mentioned above. As pointed out the values for grasses, except real desert species, were the highest, then followed ordinary Karroo bush, then Karroo bush containing much salts, like Old Man Salt or Ganna, the trees of dry habitats and then succulents. Yet the series will be very different when we take into consideration the absolute weight of the transpiring organs of all those plants. It is not realised how light grasses are, and to get a pound of grass leaves in the interior of South Africa, one has to cut a good 10-15 tufts. It is perhaps also not sufficiently realised how much surface area these tufts occupy. To obtain 1 lb. weight of Karroo bush leaves, a larger number of plants has to be stripped, although, of course, a lot of lignified material stays behind. And what about trees? One very small tree of *Combretum* or *Protea* may have 14 lbs. of leaves, one *Acacia mollissima* (black wattle), 160 lbs., a *Eucalyptus* 40 lbs. To get a basis of comparison we really have to compare from what radius of soil the different plants take the water. A wattle covers an area of 36 sq. m.; in Bechauanaland it has been calculated that only 16 per cent. of the soil is covered by grass tufts. The surface occupied by the wattle tree would therefore carry 36 tufts of grass each yielding about 50 gr. of leaves, a total of about 4 lbs. of leaves. For Karroo bush, where a morgen carries 30,000 plants, the 36 sq. m. of soil surface occupied by the wattle would carry about 3·2 lbs. of leaves. I do not want to bother you with all the intermediate calculations, but only to say that it is obvious that the transpiration of the trees is not 40 times smaller than that of grasses. We have seen that it is smaller, even considerably smaller than that of grass, on the average 1 6th-1/8th. The remaining difference has to be accounted for by the greater amount of water in the surrounding of the trees. It is generally known that trees only grow under a much higher rainfall than grass or bush, but the rainfall, at any rate the effective rainfall on dry hills, is not five times higher than in the grasslands of South Africa. We pay for trees, the most beautiful asset of a country, dearly, without realising it. Our natural forests are, of course, so far spaced that there never will be danger of their drawing too much water out of the soil. Moreover, their undergrowth is so dense that the rainfall is much more effective than on shaly hills. On dry hills, indigenous trees never become tall, and their formation is a very open forest with plenty of undergrowth; a forest of trees in dense espacement with 160 lbs. of leaves per tree could not survive for a long time. Why? Because the trees would draw too much water from the soil and the water would not be readily replaced by the rain.

The absolute amounts of rain which fall on 100 sq. m. in the dry grass veld of Bechuanaland, in the broken veld of the Free State, and surroundings of Pretoria are about 4·68 million kg., 3·38 million and 7·8 million kg. of water, respectively. Enor-

mous amounts, when you come to think of it, and yet if the natural transpiration of the vegetation covering the soil is taken, and allowance made for evaporation where the soil is poorly covered, it is found that the rain in the grassveld of Bechuanaland in good years is just sufficient to keep the grass alive. The soil could not carry a denser covering, even allowing for shade diminishing the rate of evaporation, it just balances, but if a prolonged drought comes, permanent wilting sets in. In the Karroid area conditions are different, as, allowing for evaporation, the soil under normal condition can carry its flora, just because the Karroo bushes, contrary to the grasses, decrease their transpiration with decreasing water content of the ground. On the other hand the run-off of water in the Karroo is much larger than in Bechuanaland, and this accounts, as in a vicious circle, for the sparse vegetal covering of the broken veld. The amount of transpiration ot the same species of grass, *Themeda*, is the same in Bechuanaland as at Pretoria as Miss Mes has shown. The Pretoria veld is, however, more densely covered with *Themeda*, but the increased rainfall of the Transvaal will easily compensate for the greater water loss per surface soil. It is really only when we come to trees that we begin to wonder whether the supply of water is sufficient. In years with normal rainfall it certainly is for most South African trees, even more than sufficient. A simple calculation shows that South African trees on dry soil use only about 50 per cent. of the rain water, the rest is available for undergrowth, unavoidable run-off, and evaporation; even if in some years the rainfall is insufficient, the trees draw the ground water from depths to which the other plants cannot penetrate, and thus in spite of some drought years trees do not immediately give in and die. If, however, we have to do with densely planted trees like wattle plantations, trouble may start; as the wattle has a high transpiration power, the plantation may draw more out of the soil than can ever be replaced. For a time the ground water supply can stand this, but a time may come when it cannot do so any longer.

Summarising the results, it has been pointed out that enormous quantities of water are used by a vegetation, whether bush, grass or trees. It has been shown that *ceteris paribus* grasses are the most likely to squander water and certainly use the most per amount fresh matter, and that explains why the vegetation of the broken veld changes so much with the changing rainfall. Grasses can only survive with a much higher superficial water supply than Karroo bushes with deeper roots and smaller transpiration.

If the question of the high transpiration power of xerophytes sustained by the Russian school is once more considered, we may be a bit puzzled. The Karroo plants seems to be a case in point; they show a high transpiration when they have plenty of water, and they restrict their water loss with the declining water supply of the soil, and also restrict transpiration even with an adequate

water supply during the hottest part of the day. The grasses of the interior of South Africa have a high transpiration power, and decrease their water loss but little, if at all, with the diminishing soil moisture, and in times of drought are in danger of wilting. Although they exist in a semi-arid habitat, they cannot be considered as xerophytes in the sense of the Russian school, because they die owing to their high transpiration rate. They do not show a dormant state as the Karroo bushes display in a time of prolonged drought. Trees, especially when young, have rather a long dormant state in winter in a semi-arid climate, and inhibit transpiration over hot spells of the day. Even with a good water supply they, except the *Leguminosae*, have not a high transpiration power. Although from their habitat one is certainly inclined to class them as xerophytes, their transpiration power does not agree with Maximow's theory, of a large water loss in the sun. We can only sum up the position of the transpiration problem of the different vegetation types with the words of a German scientist: Every country, every desert has its own special problems of transpiration, of the water supply and water loss by the plants.

We can only record the phenomena of nature and not force them into our theories .

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THE OLD SURVIVING TYPES OF MAMMALS FOUND IN THE UNION

BY

Dr. Austin Roberts,

The Transvaal Museum, Pretoria.

With 8 Text Figures.

Presidential Address to Section D, delivered 8 July, 1937.

Analysis of the characters and distribution of our fauna produces some interesting features to which I wish to draw attention, since it is by such analyses we may some day be able to gain evidence of the age. or permanence, of the physical conditions prevailing in this country. By such comparisons one cannot avoid the conclusion that there have been but small changes over a great period of time in South Africa. This controverts a common pessimistic view that our rainfall averages are continually dropping and that some day South Africa will become an arid desert. It seems to me more likely that there have been minor fluctuations in cycles, but that on the whole the average rainfall must have remained much the same for an immense period. That the balance of Nature has been, and will continue to be upset by overstocking, grass-burning and cultivation of the virgin veld under European settlement is to be expected; and the larger animals having been depleted, if not exterminated, by the pioneers, our vision of the country and its natural fauna is somewhat spoilt and difficult to portray. Nevertheless, despite the changes and their effect on the fauna, sufficient of the latter remains to furnish material for discussion and speculation. It is not my intention here to disclaim against the disappearance of the fauna—a sad but apparently inevitable corrolary of European " civilisation "—but to discuss the characters and distribution of some of our species of mammals with a view to throwing some light upon their age of establishment here.

When making such analyses we have to bear in mind a number of qualitative factors. Firstly, the nature of the animals and their food requirements. Secondly, their ability to elude destruction from enemies—not including diseases, a field of study that still remains to be closely studied in relationship to distribution of species. Thirdly, the nature of the soil, the amount

of rainfall, altitudes and latitudes, and other local physical features which go to the composition of a terrain and produce the conditions suited to the existence of the animals. Fourthly, whether the animals have originated in the north and after radiation southwards have adapted themselves to the conditions of the south, or whether they have evolved in the south and remained there or radiated into the tropics.

Since most animals can be regarded as survivors only of types that have gone before, it may seem rather a plagiarism to speak of "old surviving types." There is, however, a decided distinction between old forms that still survive with little apparent change in their characters, and recent ones that have changed from the ancestral types and occur side by side with the old types. Precisely what constitute the characters by which we are to define the old and new species is not readily expressed, since that would mean embarkation upon a lengthy treatise in no way possible in a short paper such as this. Briefly, the difference lies in the structural characters, such as we find when comparing, firstly, the orders, secondly the families, thirdly the genera, fourthly the species, and lastly the sub-species. It requires no great perception to realise that such isolated mammals as elephants, rhinoceroses, hoppotamus, antbear, scaly anteater. represent ancient types, and in descending scale we are able to judge of the age-value of characters by the importance of the differences. We are able to judge very largely by the constancy to type of the structural characters, making due allowance for some remarkable departures from the norm, such as we find in "flying" squirrels for example. The stage we have reached to-day in systematic arrangement of the major to minor groups has its basis upon the accumulated study and deductions of thousands of students of both living and fossil types of animals, so that we are reaching a stage when speculation is giving way to certainty in so far as available evidence permits.

Some orders of mammals show a wide distribution over the universe in the past, but a restricted distribution at the present time; on the other hand, a few orders of mammals seem always to have had a limited range, such as the *Chrysochloroidea* that are confined to the African continent. In dealing with the families we naturally find more that have a restricted distribution; genera are even more restricted and species are the most restricted of all. Much of this distribution depends upon the habits of the animals, those that wander most being the most widely dispersed, those that are the most highly specialised being conversely confined to limited ground. Thus the larger carnivorous and herbivorous types are usually widely dispersed, whereas their smaller allies are much more local in distribution. The former have better prospects of survival than the latter in the event of great physical changes taking place. That such physical changes do affect the continued existence of species is seen in the former existence of African types of antelopes and

the giraffe in India, and the hyena in the British Isles, which are to-day still found in quantities in Africa. Some West African types of mammals, such as the civet, palm civet, pangolin, so closely resemble similar animals in southern Asia that it has long been recognised that there must formerly have been a much more contiguous connection between the two regions than is seen to-day. There is, in fact, considerable evidence of change in the northern part of Africa within comparatively recent times, but in the south the only evidence we have is that the dry area of South West Africa must formerly have extended without interruption north-eastwards to North East Africa, as seen in the presence of oryx and dikdik antelopes, which are now divided by a broad belt of less arid country where the animals no longer exist.

Up to quite recently, very little had been discovered in the way of fossil types of mammals in South Africa, so that we are somewhat at a loss as to earlier types that may have existed here; but all that has been found does not indicate any great change having taken place, and the concensus of opinion seems to be that this part of the continent has remained much the same for a great period of time. Changes that have taken place in South Africa seem to be rather eastern than western within comparatively recent times in South Africa, and in degree only. the once contiguous forests that extended from the tropics southwards along the eastern escarpment to the southern Cape province having been broken up into patches that are more or less isolated. Evidence of this is seen in the presence of forest-frequenting types like the blue duiker, tree dassie and forest mice of the genus *Grammomys*, which do not occur outside the dense forests. That these forests are old is seen in the occurrence in them (though also in the scrub) of the oldest of the Crocidurine Shrews of the genus *Myosorex*. In the grassveld we have also an interesting rodent in the genus *Mystromys*, which is the only representative in Africa of the northern family of *Cricetidae*, now occurring only south of the tropic of Capricorn, and seems to indicate a very early connection with the palaearctic region. On the west, on the other hand there would seem to have been less change, as we have there a number of generic endemic types and even a family of rodents, whose nearest relatives are said to be placed in South America. From these little bits of evidence, it is extremely difficult to form definite conclusions, and we shall therefore have to await the result of palaeontological research before attempting them. But one fact does stand out quite clearly, namely, that the evolution of generic types and very distinct species in the south has taken place, and the direct origin of some of them is obscure.

South Africa to-day shows great contrasts as between the east and west and as between the winter-rain region of the south and the summer-rain region of the east and north. Temperatures varying also with latitude and altitude, and the amount

of precipitation of rain varying considerably from point to point, especially diminishing westwards, while the soil conditions also bear upon the prevalence of plants and animals, a great variety of conditions of environment is produced within a comparatively small compass. This great variety of conditions produces one of the finest fields in the world for comparative studies. Even to-day, after so much field work has been done we are continually encountering surprises. The dry conditions so often overlap the moist that there is as often an intermixture of the fauna that is puzzling to the stranger. Moreover, the smaller mammals are so often secretive and difficult to procure that we are far from knowing as much about them as we would wish. Nevertheless, in broad outlines we are beginning to understand the why and wherefore of the distribution of the species in this puzzling region of South Africa, and the more we learn the more interesting does the subject become. Among such puzzles may be mentioned the golden moles (*Chrysochloridae*), amongst which there are a number of species and genera of very circumscribed distribution, whose survival in a country so subject to uncertainties of rainfall will always remain a mystery.

In order to understand the subject as I wish to deliver it. we may place the mammals in four categories, namely:—

1. Purely tropical genera and species, that do not penetrate far into the temperate parts of South Africa, and then only in the hof low-lying coastal tract of the east as far as Zululand and Natal.

2. Genera and species which are common to both tropical and temperate parts of South Africa.

3. Genera and species which seem to have originated in South Africa, but have penetrated northwards into the tropics, though not to the north of the equator.

4. Genera and species of southern origin which have not extended their range north of the tropic of Capricorn.

For purposes of comparison these genera and species will be dealt with in systematic order in two sections, comprising categories 1 and 2 in the first, and 3 and 4 in the second

Order *Chrysochloroidea* (golden moles). Totally blind mammals that live in burrows underground, some species coming on to the surface to search for their insect food or worms.' In category 1 we have only the genus *Chrysotricha*, species *obtusirostris* and *chrysilla*, occurring from Beira southwards to northern Zululand. In cat. 2 we have the genus *Chlorotalpa*, with species very locally distributed. as follows: *sclateri* in the comparatively dry area on the plateau west of Beaufort West and along the Stormberg to southern Basutoland; *guillarmodi* in northern Basutoland; *montana* at Wakkerstroom; *duthiae* from Knysna to Port Elizabeth; *tropicalis* from Tanganyika Territory; *fosteri*

from Mt. Elgon; and I believe the following species, which were formerly placed in the genus *Chrysochloris* in its broad application before the genus *Chlorotalpa* was founded: *leucorhina* from Angola; *cahni* from Cameroons; *congicus* and *vermiculus* from the Congo region; and *stuhlmanni* from Ugogo. The extremely local distribution of these species in some parts of South Africa is a good indication of how these animals, despite their disabilities, have been able to survive. Any change in the conditions of their environment must have led to their extinction.

All the rest of the members of this order are restricted to the temperate parts of South Africa and will be dealt with hereafter.

Order *Insectivora*, family *Erinaceidae* (hedgehogs). Only one genus and species (*Atelerix frontalis*) occurs within our limits and comes under cat. 2, as it is distributed from the tropics to the eastern Cape Province. Members of the family occur in Europe and Asia as well. Family *Crociduridae*. This family of small insectivorous mammals contains two genera (*Crocidura* and *Suncus*) of wide distribution over Africa, southern Europe and Asia, which therefore come under cat. 2. A third South African genus, *Myosorex*, represents the oldest type in the family, and will be dealt with later as it comes under cat. 4. Other genera occur beyond our limits, but do not here concern us.

Order *Carnivora*, family *Viverridae*. The genera *Civetta* (civet), *Nandinia* (palm civet), *Rhynchogale* (Mellor's mungoose), *Bdeogale* (thick-tailed mungoose), *Paracynictis* (Selous' mungoose), and *Helogale* (dwarf mungoose) are all in cat. 1, some extending farther south than others. In cat. 2 we have the genera *Calogale* (slender mungooses), *Herpestes* (ichneumon), *Atilax* (water mungoose), *Mungos* (banded mungoose), and *Genetta* (genets); amongst the species of these genera *Genetta rubiginosa* and *G. zambesiana* and *Calogale sanguineus*, *C. nigratus* and *C. shortridgei* may be placed in cat. 1; but some other species fall under cat. 3 or 4, to be dealt with later. Family *Hyaenidae*. The spotted hyena (*Crocuta*) comes under cat. 2, and brown hyena (*Hyaena brunnea*) under cat. 3—to be mentioned later. Family *Proteleidae* (aardwolf). The only species comes under cat. 2. Family (*Felidae* (cats). All the species come under cat. 2, except the genus *Microfelis*, which comes under cat. 3. Family *Canidae* (dogs, jackals). All come under cat. 2, except the side-striped jackal (*Chaeffia adusta*), which comes under cat. 1, and the silver fox (*Cyanolopex chama*), which comes under cat. 3. Family *Melidae*. The ratel (*Mellivora*), otters (*Lutra* and *Aonyx*) and muishond (*Ictonyx*) come under cat. 2, but the snake muishond (*Poecilogale*) under cat. 3.

Order *Artiodactyla*, sub-order *Bunodonta*, families *Hippopotamidae* (hippopotamus) and *Suidae* (pigs) and sub-order *Selenodonta*, families *Giraffidae* (giraffes) and *Bovidae* (buffalo

and antelopes) come under cat. 2, with the exception of some genera and species of *Bovidae* that come under cat. 1 (such as nyala, situtunga, waterbuck, puku, lechwe, sable, roan, sassaby, blue wildebeest, red duiker and suni antelopes), and a few species and genera that come under cat. 3 or 4 and will be dealt with hereafter.

Orders *Proboscidea* (elephants), *Tubulidentata* (aardvark) and *Pholidota* (pangolin), all come under cat. 2.

Order *Hyracoidea*, family *Procaviidae* (dassies). The genus *Heterohyrax* comes under cat. 1, but the other two genera (*Procavia* and *Dendrohyrax*) come under cat. 2.

Order *Perissodactyla*, family *Rhinocerotidae* (rhinoceroses). Both genera comprising the white and the black rhinoceroses come under cat. 2, but the case of the former is interesting on account of its occurrence to the north and south of the equator with a wide gap intervening in its distribution between these points. Family *Equidae* (zebras). One species of the genus *Hippotigris* (Burchell's zebra) comes under cat. 1, while distinct species exist respectively in the north (Grevy's) and south (Cape mountain zebra), the latter with a relative (Hartmann's zebra) in South West Africa and Angola. The former of the southern zebras comes under cat. 4 (to be mentioned later) and the latter under cat. 2, or perhaps 3.

Order *Rodentia*, an extensive one that requires careful treatment: Family *Hystricidae* (porcupines), widely distributed, with one species under cat. 2. Family *Thryonomidae* (cane rats). One species occurring with us comes under cat. 1, and others in the northern tropics. Family *Petromidae* (noki). One genus with two species represent this family, occuring only in the mountains of South West Africa and therefore one of the curiosities of that region, as indicating how little change must have taken place there over an immense period of time. Family *Pedetidae* (springhare). Another curiosity represented by one genus and species that will be dealt with later as coming under cat. 3. The last three genera were at one time closely associated under the heading of *Hystrichomorphae*, representing very ancient types related to the porcupines. The cane rats have survived from their partly aquatic habits, the noki by finding shelter in the dry mountain rock crevices in South West Africa and the springhare by its activity in burrowing in sandy soil.

Family *Sciuridae* (squirrels). These are widely dispersed over the universe, mainly in the tropics and arboreal in habits, but with strictly terrestrial off-shoots where the forests have disappeared. The South African arboreal species only extend southwards to northern Transvaal and coastal Zululand; but in the west occurs a genus (*Geosciurus*) containing one species (*capensis*) in cat. 3 and another (*princeps*) under cat. 1, the latter

found in the rocks of the mountains of South West Africa and the former in the calcareous veld of the plains—having some analogy to the case of the noki and the springhare.

Family *Graphiuridae* (dormice). A widely dispersed group of small, bushy-tailed nocturnal rodents having some resemblance to the diurnal squirrels, all the species apparently hibernating for the colder months of the year, at any rate south of the tropics. Most of them come under cat. 1 or 2, but one genus, *Graphiurus*, is quite distinct and comes under cat. 4, to be dealt with later.

Family *Bathyergidae* (mole rats). A family of burrowing mole-like rodents that is confined to Africa. Its most remarkable genus (*Bathyergus*) and another prettily coloured genus (*Georhychus*) come under cat. 4, but all the other genera come under cat. 1 or 2. Beyond our limits are two more curious genera in *Heliophobius*, which has five or six molars where the others have four, and *Heterocephalus*, which has no hair and only two or three molars. Several species of the tropical genus *Cryptomys* come under cat. 4.

Family *Gerbillidae* (gerbilles)). A widely dispersed family of which one genus (*Tatera*) extends throughout Africa into India, another genus (*Gerbillus*) has a discontinuous distribution in the west of South Africa and again in east and north Africa, and a third (*Desmodillus*) is confined to South Africa, coming under cat. 3. Several distinct species of the genera *Tatera* and *Gerbillus* come under cat. 3 or 4.

Family *Otomyidae* (vlei and Karroo rats). Several species in the genus *Otomys*, which comes under cat. 2, are strictly South Africa, while the genera *Myotomys*, *Parotomys* and *Liotomys* come under cat. 4 or 3, to be dealt with hereafter.

Family *Muridae* (rats and mice). Of the sub-family *Dendromurinae* two genera come under cat. 2, but one (*Malacothrix*) is better placed in cat. 3 and is remarkably different from the other two. The rest of the murine genera come either under cat. 1 or 2, with an exception, perhaps, in *Petromyscus*, a genus recently discovered in the mountains of South West Africa, which would come under cat. 3. As might be expected, there are a few distinct species that come under cat. 4 or 3 of these murine genera, but there is nothing remarkable about any of them.

Family *Cricetidae*. One genus (*Mystromys*) with a single species *albicaudatus* (white-tailed rat) is remarkable for being the only representative of the family—which is found in the north-temperate region—in this continent. It comes under cat. 4, to be dealt with later.

Order *Lagomorpha*, family *Leporidae* (hares). Two species of the widely dispersed genus *Lepus* occur with us and come under cat. 2; but another genus, *Bunolagus*, comes under 4, and a third, *Pronolagus*, under cat. 3, both to be dealt with hereafter.

Order *Chiroptera* (bats). These animals having the power of flight seem to have no distinct genera within our limits, and only a few species that come under cat. 4 or 3, so that we may pass them by.

Order *Menotyphla*, family *Macroscelididae* (elephant shrews). This family is peculiar to Africa, and presents some of our greatest curiostities. All the species are insectivorus, hop on long hind legs somewhat like kangaroos and have protruding noses. Two genera are tropical, one (*Rhynchocyon*) containing the largest species and occurring only north of the Zambesi river and the other (*Petrodromus*) extending as far south as Zululand. Two more genera, containing small species (*Elephantulus* and *Nasilio*) come under cat. 2 and 1, while the fifth genus (*Macroscelides*) comes under cat. 4 and presents the most remarkable developments of the skull of any of them—to be dealt with hereafter.

Order *Primates*, family *Cercopithecidae* (baboons and monkeys) and family *Lemuridae* (galagoes) are mainly tropical, and come under either cat. 1 or 2. Baboons have extended into the mountains of the south and west, but monkeys and galagoes have only extended respectively as far south as eastern Cape Province and Natal on the east, and Orange River on the west.

Having briefly run through the genera and species that fall under cat. 1 and 2, we come to the more interesting ones under cat. 3 and 4 containing the South African endemic types. They will be dealt with in the same order of arrangement as those above.

Order *Chrysochloroidea*. These golden moles are known only from Africa, the great majority of species and most of the genera being known only from temperate South Africa, especially where there is a fair rainfall. In the hard soil of the drier parts of South Africa and the sandy soil of the dry Kalahari they do not appear to have been able to exist, in the former from the difficulty in burrowing, and in the latter from the paucity of insect larvae and worms upon which the animals subsist; but, curiously enough, several species and a distinct genus seem to have managed to exist in the dry area of Little Namaqualand, presumably because the plant life adapted to that region has been sufficient to support a large quantity of insects, upon the larvae of which the golden moles have been able to exist. The peculiar genus, *Eremitalpa*, is long-haired, and probably, like two other long-haired genera, *Chalcochloris* and *Bematiscus*, seeks a large part of its food during the night on the surface of the ground. The largest species is *Chalcochloris trevelyani*, which occurs only in the Pirie and adjoining forest areas to the coast of Pondoland, where there is a giant worm (*Microchaetus* sp.) that comes above ground during the night; the golden mole has survived, however, only where it has the shelter of forest growth. The next in size is *Bematiscus*, which is confined to the grass-veld areas of Natal,

eastern Cape Province and Orange Free State and highveld of Transvaal; it comes above ground apparently only after rains have fallen, probably in pursuit of the worms that then emerge. The remaining species of the genera *Chrysochloris*, *Amblysomus*, *Chlorotalpa* and *Neamblysomus*, as well as the tropical *Chrysotricha*, seek their food almost entirely underground, where they form long tunnels in search of it. The genus *Chrysochloris* is peculiar in having a swelling on the cranium known as the temporal bulla, which none of the others possess, and the function of which is not clear, but may be in some way connected with the auditory organs, in function somewhat akin to the extraordinary developments we see in *Macroscelides*, *Desmodillus*, *Pedetes* and the enlarged bullae of *Parotomys* and *Liotomys*. *Amblysomus* occurs from Stellenbosch eastwards to Natal and Zululand and northwards to the eastern Orange Free State and Transvaal. *Neamblysomus* occurs only at Woodbush, as far as we know at present. The two latter genera differ from *Chlorotalpa* mainly in the number of teeth.

Special interest attaches to the existence of these golden moles and the great differences to be seen in their structural characters, since the conditions of their environment must have remained the same for a very great period of time to permit of such high specialisation as they have developed and for the animals to have survived.

Order *Insectivora*. Special interest attaches to the existence in South Africa of the oldest genus in the family, *Myosorex*, which still retains a minute premolar in the maxilla which the others have lost. Its range does not extend north of the tropic of Capricorn, while the other genera extend over the continent to Southern Europe and eastwards to the Malay Straights and the Malagasy Islands.

Order *Carnivora*. In the family *Viverridae* we have only one species of genet (*Genetta tigrina*) and one species of slender mungoose (*Calogale pulverulentus*) strictly confined to the south; but two genera, *Cynictis* and *Suricata*, seem to be typically South African, occupying the dry western parts from the Karroo to Ngamiland and Ovamboland, the first related to the tropical Selous' mungoose (*Paracynictis*) and white-tailed mungoose (*Ichneumia*), and the second to the banded mungoose (*Mungos*). Both *Cynictis* and *Suricata* are gregarious and live in burrows, and show quite marked differences from their tropical allies. Of the family *Hyaenidae*, the brown hyena (*Hyaena brunnea*) seems to be of South African origin, though it has pushed its way northwards to Tanganyika Territory, beyond which is found its congener the striped hyena (*Hyaena striata*), which extends thence to southern Asia. In the cats (*Felidae*) the only notable genus is the small black-footed cat (*Microfelis nigripes*), which occurs in the dry west, from the eastern Cape Province to Damaraland. Of the family *Melidae*, the weasel-like snake muishond (*Poecilo-*

gale) extends northwards into the tropics, but not north of the equator, and seems therefore to be of southern origin. It is quite distinct from the northern animals in colour, skull and teeth, the black colour with white dorsal stripes reminding one rather of the African muishonds (*Ichonyx*).

Order *Artiodactyla*, family *Bovidae*. In the antelopes we have quite distinct genera in the *Pelea* (Vaal rhebok), *Connochaetes* (black wildebeest), *Antidorcas* (springbok), and species in *Alcelaphus caama* (red hartebeest), *Damaliscus pygargus* (bonteboks), and *D. albifrons* (blesbok), the extinct *Hippotragus leucophaeus* (bloubok), *Oryx gazella* (gemsbok), *Redunca fulvorufula* (mountain reedbuck) and *Nototragus melanotis* (grysbok). The *Pelea* is the most strikingly distinct and its affinity is obscure; it frequents the mountain plateaux and does not extend beyond the tropic of Capricorn. The black wildebeest is also strikingly distinct in the shape of its horns, which dip forward and upwards, unlike those of any other antelopes. The springbok is merely a southern type of gazelle, and the bontebok and blesbok are off-shoots from the hartebeests, in which there is a fair range of variation in the species still existing in the greater part of the continent. The grysbok (*Nototragus melanotis*) is an off-shoot from the oribi (*Ourebia ouribi*) of the grassveld of the east and north, which has taken refuge in the scrub at the foot of mountains after being harried in the plains; on the other hand the steenbok (*Rhaphiceros campestris*) is a solitary plains frequenting and fleet-footed relative of the grysbok, and widely distributed. A northern tropical species of grysbok (*Nototragus sharpei*) probably originated in the south, as it does not extend north of the equator, its radiation coinciding somewhat with that of the steenbok. The Ouribi extends also over much the same range, but farther north and is more circumscribed in its habitat than the steenbok. The duiker antelopes afford an interesting study. The blue duiker, as already mentioned above, frequents only the dense forests, and yet extends from tropical West Africa southwards on the eastern side of South Africa to Knysna, with a curiously broken distribution. The tropical red duiker (*Cephalophus natalensis*) on the other hand inhabits drier scrub forests and extends southwards only along the coast of Natal. The common duiker (*Sylvicapra*) is more adaptable, and much more widespread in its distribution in consequence, as it inhabits open scrub (and even plains where the grass is long) and patches of bush throughout South Africa and over the greater part of the continent, avoiding only the large forests.

Order *Hyracoidea*. The dassies (*Procavia*) seem to have survived everywhere when rocky fastnesses are available. They are survivors of much larger mammals, of which fossil forms have been discovered in north Africa, one must conclude solely by reason of their ability to scramble about amongst rocks where

other mammals would obtain no foothold. Members of the genus *Heterohyrax* are somewhat connectant between *Procavia* and *Dendrohyrax*, the latter confined to the trees of large forests, one species extending as far south as Knysna. Some rather interesting results have been obtained by Mr. G. A. H. Bedford, of the Veterinary Research Laboratory, Pretoria, in his studies of the lice of these animals. He has always been able to identify the lice coming from the three genera without fail, and has been able to identity the species of lice coming from the sub-species of the dassies with less difficulty than I have had in identifying the animals from which they were taken. We have in this a controversion of the usual rule where lice and their hosts are concerned. the parasites usually changing more slowly than their hosts, so that a species of louse may be common to a genus of the host and a genus of louse being common to a family of the host. But in the case of some *Procaviae*, the lice appear to have changed more perceptibly than their hosts, which seems to indicate that the hosts have remained constant to their characters for a greater length of time than is usual with other animals, the parasites in the meantime changing slowly to new forms.

Order *Perissodactyla*. The southern zebra seems to have survived like several southern antelopes, the red hare and the dassies by taking refuge in the mountains. This seems to indicate the presence at some distant time in the past of a swift-moving carnivorous animal in the plains, from which they could only escape in the rugged mountains. Elsewhere, however, a plains-frequenting zebra survived and subsequently spread over the greater part of tropical Africa, from which arose the various types known as the Burchell's zebra, and probably also the now extinct South Africa quagga (*Hippotigris quagga*). The Hartmann's zebra survived in the same way as the Cape mountain zebra in the rugged mountains of South West Africa and Angola. To the north of the equator the Grevy's zebra survived at the same time as the Cape mountain zebra.

Order *Rodentia*. The most interesting relicts of old types of rodents are undoubtedly the noki (*Petromys*) of the dry rocky mountains of South West Africa, the springhare (*Pedetes*) of the sandy plains, and the cane rats (*Thryonomys*) of the tropical tangled vegetation of rivers and streams, all three families of which are well isolated. The first is limited to South West Africa, the second to the sandy areas of South Africa and thence northwards to Angola and Tanganyika Territory, and the third is tropical in distribution. Next in interest come the ground squirrels (*Geosciurus*), of which one species (*princeps*) is found in the rocky Kaokoveld, and the other more widely distributed over the calcareous veld from the Karroo northwards to Ovamboland and Ngamiland, on the east to Orange Free State and western Transvaal. There seems to be an analogy between these two species and the noki and springhare as regards their habitat and survival.

Another terrestrial squirrel is found north of the equator (*Xerus*), but it has been stated to be of different origin. In view of the evidence that the gemsbok and dikdik antelopes, the rodent genus *Gerbillus*, the ostriches, and a number of other animals being related in the north and south, showing a former existence of an arid belt connecting up the north and south, I feel dubious as to the correctness of that statement. The differences that have developed in the north and south in the ground squirrels may well have been deceptive, as in the main there is a great similarity between them. In the *Graphiuridae* the typical genus, *Graphiurus*, is the most distinct in the family in structure and colour, and probably the oldest type. It is confined to the south, extending northwards only to the Orange Free State. In an allied genus (*Gliriscus*) a very distinct species occurs in South West Africa, other members of the genus occurring to the east and north in the tropics. In another genus (*Claviglis*) there are a number of species, one of which extends southwards on the east as far as Knysna forests. Amongst the mole rats (*Bathyergidae*), the typical genus (*Bathyergus*) is again one of the most distinct. It is confined to the sand dunes of the south and south-west coastal tract, and differs from all other genera in having the base of the incisors above the molars instead of behind them and the anterior face of the upper incisors grooved, the muzzle protruding, the lower jaws firmly fused together and the fore-claws long and strong, to mention the most outstanding differences only. In the next endemic southern genus, *Georychus*, which extends northwards only to eastern Transvaal, the molar teeth show a rather primitive infolding not seen in other genera, one fore-claw is long and the colour characters are distinct; in other respects it is not unlike the members of the genus *Cryptomys*, of which there are many species, some of them peculiar to South Africa. In Mozambique occurs another peculiar genus, *Heliophobius*, which has five or six molars, where those mentioned above all have four, and in Somaliland occurs another strange genus, *Heterocephalus*, characterised by having only two or three molars, a rather long tail for a mole, and the skin naked.

Amongst the *Gerbillidae*, the most remarkable genus is *Desmodillus*, a plump, rather short-tailed animal with short ears and enormously developed auditory and occipital bullae, much as is seen in *Pedetes* and *Macroscelides*. It occurs in the calcareous veld of the west, rather more extensively than the ground squirrel. It was formerly placed in the genus *Pachyuromys* that occurs north of the equator, and there is therefore a possibility of its being another instance of northern and southern relationship, as in the gembok and dikdik antelopes and others above mentioned. In one species of Gerbille (*Gerbillus vallinus*) found in Great Namaqualand there is seen a tendency to develop occipital bullae such as we find in *Desmodillus*. Of the genus *Tatera* one species (*T. afra*) appears to be quite

distinct and confined to the south-western sandy area of the Cape Province. Other species, such as *T. brantsi*, appears to link up with tropical ones. Of the *Otomyidae*, the Karroo rats of the genera *Myotomys*, *Parotomys* and *Liotomys* present a most interesting study in evolution of structural characters of the skull and dentition in the various species, which often occur side by side. In the typical genus, *Otomys*, we have also several distinct species confined to South Africa and others which appear to link up with tropical ones extending to Angola and north-east Africa. In Angola is another genus, *Anchotomys*. Of the mice, *Malacothrix* is very distinct from the related genera *Dendromus* and *Steatomys*, in structure, colour and habits; it extends over the western part of South Africa, from the Cape district northwards to the Kalahari and Ovamboland. In Abyssiania occurs a genus, *Chortomys*, which shows some affinity to *Malacothrix* in the skull and colour markings, but otherwise is more like *Dendromus*, which, together with *Steatomys*, is widely dispersed over the continent. Another link with the north is the isolated genus *Mystromys*, which is found only in the south, but is a member of the cricitine group found only in the northern hemisphere. Its dispersal southwards must have taken place in very early times. Of the true rats and mice the only genus worth commenting on is *Petromyscus*, recently discovered by Captain Shortridge in Great Namaqualand—another interesting case of isolation in that dry tract of mountains.

Order *Lagomorpha*. Amongst the hares there are two very interesting genera, *Pronolagus*, containing the red hares, which are confined to rocky ground in South Africa, but have extended northwards to Nyasaland, and *Bunolagus*, the brown-tailed hare, which is known by only two specimens from Deelfontein and one from Calvinia. The red hares are rather plumper-looking animals than the true hares, usually mainly pinky reddish, with shorter ears and legs than the true hares, and the brown-tailed hare has some resemblance to it, except that the ears and hind feet are longer, the soles much more heavily covered with hair and the tail is brown. The direct origin of both genera is obscure.

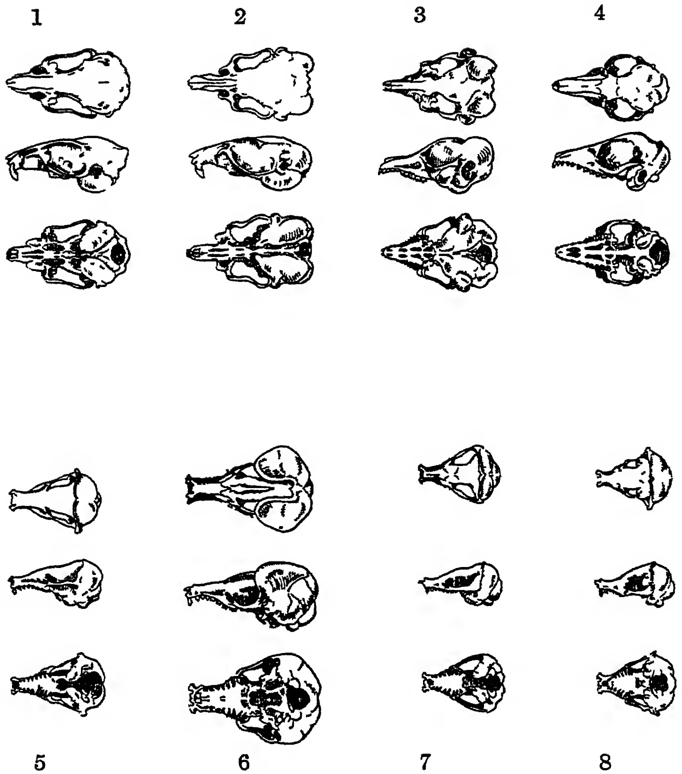
Order *Menotyphla*. The most strikingly distinct of the elephant shrews is the typical genus *Macroscelides*, in which the enormously developed auditory and occipital bullae surpass even the same development seen in *Desmodillus* and *Pedetes;* this is correlated with a shortening of the ears and is seemingly a compensation for the deficiency. Such a highly developed specialisation cannot have evolved in a short period, and adds to the conclusion that its habitat cannot have changed much over an immense period of time. In none of the other genera of the family is there any tendency to develop in the same way in the bullae. In another genus, *Elephantulus*, the majority of species are very locally distributed over certain rocky dykes and hills, the exception being a species (*intufi*) that occurs in the scrub of the dry west. Another widespread genus is found

in *Nasilio*, also found in the dry scrub, but over the greater part of the continent, which is apparently older than the others, as it still retains the hindmost lower molar which the others have lost.

Having now run over the comparative part of the subject and shown which genera and species are peculiar to South Africa, and how very distinct most of them are from their nearest relatives, I may conclude by a brief review of the whole subject. Firstly, we have seen that there must formerly have been a more direct connection with the arid north and south than is seen to-day, a moist belt having become interposed that has cut them off at some time in the not distant past, but sufficiently far back to have allowed for considerable changes in the animals so cut off. Even farther back conditions of environment must have been distinct in the area around or to the south of the Orange River, for the origin of some of the Chrysochlorids, *Bathyergus*, *Macroscelides*, *Myosorex*, *Graphiurus*, *Malacothrix*, *Pelea*, and a number of others, seems to date farther back than the slight differences to be seen in the gemsbok and dikdik antelopes. The fact that *Petromys* and *Pedetes* represent ancient types confirms this view, and on the whole there is so much evidence that the present conditions have prevailed for a great period of time with very little change that we have here a most interesting field for speculation and future enquiry. That the eastern part of South Africa has changed is seen in the distribution of at least two genera, the blue duiker and the tree dassie; but this by no means shows that it goes as far back as the intervention of the moist belt across Central Africa, which has cut off the arid parts of the north and south, and most certainly cannot have affected the Namaqualand dry conditions to any great extent. The impression one gains is that eastern South Africa has always had a plentiful rainfall and the western part has not, and the causes of the breaking up of the eastern forests have not much affected the west. There must have been fluctuations, such as we have ourselves witnessed in recent years, some years of successive droughts followed perhaps by floods; but on the whole these fluctuations have been around a mean, which has produced a stability in the characters of the species and a high specialisation that can only have evolved over an immense period. Some of the genera are so remarkably distinct, such as *Bathyergus*, *Petromys* and others, that we are at a loss to account for their relationships, and it is only here and there that we see the possibility of their having originated in northern stock, such as the isolated genus *Mystromys*. Possibly the genus *Pelea* of the antelopes is related to the gazelles, to which it has some resemblance in its straight, ringed horns and slender legs, but was driven to the refuge of mountains like the mountain zebras, mountain reedbuck, red hares, rock dassies, and thus changed considerably; but even so, I believe this must have taken place a very long time ago. The fact that the golden moles (*Chryso-*

chloridae), despite all the disabilities they labour under, have been able to survive goes to show that there cannot have been very great changes in the south and east, and even in Little Namaqualand, and this permanence must have lasted for a very great period. Yet we have the puzzling fact to face that if the *Pelea* did originate from a plains-frequenting gazelle-like stock, there must have been a hiatus before the more recent gazelle-like springbok found its way south and established itself in the Karroo. Such southern radiation may have coincided with the return of the plains-frequenting zebras, long after the mountain zebra had taken refuge in the mountains. Then again, we may assume that the grysbok was driven to the hills when still an oribi-like antelope in the southern Cape Province, later finding its way back to the plains as the steenbok. The oribi itself may have disappeared completely in the south and subsequently found its way southward again from the north, reaching as far as Uitenhage. Of the larger antelopes, we have the curious survival of the bloubok (*Hippotragus leucophaea*) until a century ago in a restricted area in the south, while its congeners have not since found their way so far south. It was probably a survival of a more primitive form of this genus, a real relict species that by some chance had escaped destruction until Europeans appeared on the scene. Perhaps the bontebok and the blesbok are also more primitive than the tropical sassaby to which they are related, but of this I am not sure. The red hartebeest, eland and kudu may have always been found in the south, but may quite as likely have radiated southwards in comparatively recent times. Of the really ancient types, such as the elephant, rhinoceroses and hippopotamus, little need be said, as they are not likely to have developed any marked differences in structure by which one could make comparisons.

It will be seen from the preceding discussion that we have still much to learn about the past history of our mamalian fauna. For further enlightenment we look to the palaeontologists. So far very little evidence has been forthcoming from fossils; but the activities of palaeontologists are bound to produce a great deal in the near future. Dr. Broom's recent discoveries in the limestone formations of Transvaal of fossil mammals are an indication of how much there is still to be discovered, and we shall look forward with great anticipation and pleasure to the final results of his work upon them. A few fossil types that have been described from South West Africa by Stromer, important as they are, do not indicate that any great change has taken place since Miocene times in that region, the ones discovered showing comparatively little structural change when compared with the living ones. The area from which fossil mammals are most needed is the south and south-west Cape Province, and so far this has not been explored.



Dorsal, lateral and ventral views of skulls of:—

1—*Tatera lobengulae,* showing the normal type of skull of Gerbilles.

2—*Desmodillus auricularis*, showing the greatly expanded bullae, protruding backwards and upwards at the occiput.

3—*Macroscelides typicus,* showing an even greater expansion of the bullae than in *Desmodillus,* remarkable when compared with other genera.

4—*Nasilio brachyrhyncha*, showing the normal skull of *Macroscelididae*.

5—*Amblysomus hottentottus*, showing the normal and primitive type of skull in *Chrysochloridae*, though in this case with only 36 teeth in all.

6—*Bematiscus villosus*, showing the large size of the animal when compared with the others, peculiar in its shape and development of the zygomatic plates.

7—*Chrysotricha chrysilla*, showing a shorter, broader type of skull, more like that of *Chrysochloris,* but differing in teeth and absence of the temporal bulla.

8—*Chrysochloris asiatica*, showing a short broad type of skull, peculiar in having a temporal bullae, which seems to have an analogy to the occipital bullae of *Desmodillus* and *Macroscelides*, shown above, and also in *Pedetes*, and the enlarged bullae found in *Parotomys* as compared with *Myotomys* or *Otomys.*

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MAN IN AFRICA IN THE LIGHT OF RECENT DISCOVERIES

BY

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Presidential Address to Section E, delivered 8 July, 1937.

Introduction.

Physical anthropology in South Africa may be justifiably regarded as having emerged from its infancy. Up till recently the physical anthropologist's main concern was the collecting of material and the reporting on it, and his debt to this Association for allowing the pages of its Journal to be the permanent record of these reports is a great one.

The first evidence of its emergence from its childhood has been the developing of a philosophical approach to the subject, so that now science seems to have shed its *toga praetexta* and donned its *toga virilis*. The anthropologist in South Africa, while still collecting data, has now sufficient to enable him to fulfil his real function as a physical anthropologist, that is, the elucidation and definition of racial physical types.

The philosophical and biological approach has enabled him to see African types in terms of world types; he has ceased to be parochial. If perhaps at times he has looked so much at the world that he has failed to see what is on his own doorstep, it is merely evidence of the growth his subject is undergoing. Anthropology in South Africa has advanced so far that its opinions are awaited, not only by the rest of Africa, but by the world at large. East and South African finds have made the world aware of the scientific richness of Africa. The rapid opening up of Africa has unleashed an ever-increasing knowledge of physical types with their concomitant arts, crafts and cultures, so much so that the knowledge of man's history will only advance with the increasing knowledge of Africa's prehistory. It will need the concerted efforts of all our anthropologists to interpret the truth hidden in our fossils. If, in this address, I seem to take views differing from my colleagues, it is done with this wider aim in view, for we cannot expect a united opinion if all ideas are not voiced.

In his presidential address to this section, Professor Maingard (1934) made a strong plea for co-operation between workers in the various branches of the science of Anthropology—a plea

which has the complete support of all anthropologists. This does not mean, however, that the physical anthropologist, whose duty it is to isolate and recognise racial types, must accept the preconceived ideas of the cultural anthropologist, whose duty it should be, not only to describe cultures, but to trace their origins and to abide by the implications thereof; that is, he must realise that he is dealing with a science and not an art.

To take a concrete example, the ethnologist and archaeologist, aware that hand-made pottery is a vital and distinguished feature of the culture of the modern Bantu-speaking Negro peoples, have tended to fall into the trap of calling all such pottery in South Africa "Bantu," no matter the circumstances under which it has been found, and of deducing from this its relative modernity. So firmly had this view become implanted that, when, as at Mapungubwe, a rich indigenous ceramic industry is found in association with human skeletal remains of a definitely non-Negro (but pre-Negro) type, the attitude of the archaeologist has been that the findings of the physical anthropologist must be disregarded, and a Bantu origin for the whole culture assumed as axiomatic.

In the instance under discussion, the ethnologist must realise that, compared with physical anthropology, the scientific study of ceramics in South Africa is in its infancy. The features of texture, shape, and ornamentation, which in South Africa are regarded as the hall-mark of "Bantu" pottery, are so universal to the art of the primitive potter, that an experienced European archaeologist was unable to detect, in a collection of South African potsherds (including specimens from Mapungubwe and also from Zimbabwe) any feature of difference from the early Bronze Age pottery of Portugal.

It is difficult, therefore, for the physical anthropologist, with his biological training, to accept the label "Bantu" for such pots, since the term throws no light on the origins of their mode of manufacture. He could accept it only if the ceramics expert could show that such pots are found only in association with bones of a Negro facies in South Africa, that their appearance in pre-Negro South Africa, in association with bones of a pre-Negro facies, is rare and sporadic, and that along the route of Bantu migration there is evidence of sites of Negro bones associated with such pottery. Until such evidence is forthcoming the physical anthropologist must perforce withdraw and hope that the historian will unravel such tangles of racial types associated with foreign cultures, for it is outside his province, as well as that of the cultural anthropologist, to draw inconclusive conclusions which may well be irrational. Further, he finds it transgressing his ideas of the laws of probability to find an almost pure pre-Negro physical type associated with the finest flowering of a culture accredited to another physical type—the Negro, when nowhere in South Africa have Negro ossuaries yielded such rich ceramic material.

Recently, Orford and Wells (1936), Dart (1937) and myself in this Journal, in studies on the somatometry of the South African Negro have found evidence of at least five physical elements, Bush, Boskop, Mediterranean, Armenoid, and Mongolian, superimposed on a Negro physical foundation. This, on the whole, is not surprising in the light of our knowledge of racial movements and contacts of the last few thousand years of prehistoric Africa. What is surprising, however, is that Dart (1937), in his work on the /'Auni and ≠Khomani Bushmen, should find evidence of the same extra-African physical elements in such overwhelming proportions as to preclude the slightest possibility of their being due to miscegnenation with their Bantu-speaking neighbours. So completely woven into their physical pattern are these foreign elements that hybridisation of the Bush physical type with them must surely have commenced long before the Bantu-speaking peoples reached the Zambesi.

Because of this the physical anthropologist needs must ask the archaeologist and the ethnologist, to whom is the art of potmaking, of weaving, and of building in stone, due? Is it to the fundamental Negro, or the superimposed Mediterranean, Armenoid, or Mongolian elements? Did the Bantu-speaking peoples develop these arts in South Africa, or did they acquire them from the Hamitic-speaking peoples during their migrations, or were they indigenous to the "Bantu" in his ancestral home on the shores of Lake Chad?

In such circumstances it is clearly the duty of the ethnologist and archaeologist to seek to bring the findings of the physical anthropologist into line with his own conclusions, not by ignoring them, but by inquiring whether or not they throw light on the history and origins of the traits of cultures with which he is concerned.

II—A Biological Interpretation of Man's Evolution.

The great searches in the history of physical anthropology have been, firstly, for a type or chain of types which could have been ancestral to man, and secondly, the search for the direct ancestor of *Homo sapiens*. This search was thought to have been completed when Leakey (1935) claimed for his now discredited Kanam fragment that it was proto-*Homo sapiens*—the direct ancestor of sapient man. Diagrams, while being explanatory, may be confusing, and diagrams illustrating man's evolution are no exception. For the sake of clarity a line is drawn; on one side is placed a human type and his culture, below it is a lower type and his culture. It is explanatory of the sequence, but that hard and fast line may confuse. Such tables show a line, below which is Neanderthal man and above which is *Homo sapiens*. From this, there has slowly and unconsciously grown up an attitude of mind which seems to imagine the complete wiping out of one type and its total replacement by the new, and ignores the fact that the two lived side by side for some considerable

time, one advancing and the other declining. A good analogy is—supposing a diagram of present-day South African conditions were drawn up in the future, we would find a line drawn between Bushmen and "Bantu," and the inference drawn from it that the two types were not co-existent. The fact that no skeletal evidence has been found to substantiate this theory of Palaeoanthropic man living alongside Neanthropic man proves, not that it does not exist, but that it has not been found.

It is because of some such irrational methods of approach that the search for the philosopher's stone of physical anthropology—the search for proto-*Homo sapiens*—has been carried out with such zeal, and that such work as Hrdlička's (1927) has been overlooked. Arguing from the cultural associations of Neanderthal man, he asks the very pertinent question—"Why could *Homo sapiens* not be descended from Neanderthal types?—and points out that the various hypotheses for an origin for *Homo sapiens* other than from Neanderthal types are given without showing why, or how, or where he developed his superior make-up, and imply that, while he evidently developed more rapidly at first to reach the status of *Homo sapiens*, he then slackened greatly, to remain from the beginning of the post-glacial era to this day, at nearly the same evolutional level.

This confusion is largely due to the complete subordination of the biological approach to the study of man by the morphological one. If the problem is approached biologically this confusion loses some of its density.

Alsberg (1934), in adopting this method to estimate the place of *Australopithecus africanus* in primate evolution, lays down certain biological principles which can be applied, not only to solve the nature of the transition of man-ape to man, but also that from *Homo* to *Homo sapiens*.

". . . man and animal develop on diametrically opposite principles: the animal on the principle of physical or organismal adaptation, man on that of extra-physical or non-organismal adaptation, i.e. of the liberation of the body from the necessity of adaptation by extra-physical means, by 'tools.' The animal possesses a perfect body, having developed manifold structures for defence and offence, such as sharp teeth, claws, horns, swift legs, keen senses, armour, shells, stings, a heavy pelt or a thick layer of fat, poisons, scents, pigments, etc. Thus, as a result of complete adaptation to the conditions of environment, the animal's body renders full service in the decisive struggle for life. Man's body, on the contrary, exhibits a picture of utter defencelessness and helplessness, while 'all around' man it is his technique that develops, replacing man's adaptation to nature by much more efficacious means—tools."

Here seems to lie the whole key to man's evolution. The first hint there is of extra-physical tools is the indirect evidence of the fossil animal remains associated with the Taungs skull.

Broom (1934) has supplied the evidence of Dart's theory that the Taungs creature was sufficiently advanced to use weapons to trap his game and to break open the braincase and the narrow cavities. These weapons, in all likelihood, were sticks and stones in their natural state, and very probably used without any rational selection being made. From this beginning it is conceivable that later sticks and stones were selected rationally, because of their shape and size.

The great advance came when the hominid type was well established and tools were deliberately fashioned. At first, simple techniques were practised resulting in tools used for a variety of purposes. This stage lasted over a very long period, during which man's ingenuity was such that, while he could improve these techniques, he was not inventive; he could not conceive new techniques.

At this stage, man's skull, although refined as compared with those of the great apes and with his ancestral type, such as the Sterkfontein adult *Australopithecus transvaalensis* skull, was probably still a brutish thing with a massively built face, overhung by a massive supraorbital torus exaggerated by the markedly receding forehead with its prominent ophryonic groove.

Then once more man became inventive. This inventiveness manifested itself in a greater number of techniques and of implements which characterised the evolved hand-axe culture and the subsequent Mousterian. This advance in man's civilisation is equalled only by three other advances in the history of man, the advance made when man commenced to fashion weapons, and changed from the use of chance weapons to manufactured weapons. the advance which culminated in the development of art and the advance made at the beginning of the Neolithic period, when, as Schneider (1931) points out, " the New Stone Age created all the foundations of our material and spiritual civilisation—agriculture, cattle-breeding, the building of houses and boats, plaiting, weaving, pottery, solar astronomy. . . ."

The result of this greater inventiveness is the enlargement of man's ideas by later peoples, which culminated in the great perfection of tools and the development of art which characterised the succession of cultures from Aurignacian times down to the beginning of the Neolithic Age.

As such, if Alsberg's biological principles are correct, we would expect a change in skull shape and build. The skull does change. The bones have now become more delicate in construction and more delicately moulded. The teeth are reduced in size, with a concomitant refinement of the muzzle. Four types of tools gave Mousterian man greater external means of defence and attack. His teeth would be less required for tools, he had now fashioned tools to strip off bark, etc., heavy bones were now no longer required for his protection and defence, so they dwindled, giving him a more refined face.

Of recent years, one of the most helpful contributions to anthropological philosophy has been Drennan's pedomorphic hypothesis (1931). Interpreting Bolk's work, he infers that "the greater the degree of retardation or 'foetalisation,' the more human the morphology." While man was still in the evolutionary stage in which he still retained some intrinsic means of defence, it was essential that his gerontomorphic features should be developed as fully as possible, hence his strong supraorbital torus, massive unexcavated middle face, and powerful projecting jaws. With the invention of new types of weapons, i.e. with the increase of his extrinsic means of defence, the need for full development of gerontomorphic features—his intrinsic means of defence—became lessened, and he gradually became more pedomorphic.

The evolution of the supraorbital torus and of the middle face seems to indicate, as far as our knowledge goes, the method by which this refinement of the face could have taken place. If we examine a series of skulls of different degrees of antiquity, we see that in ancient types, such as Neanderthal man, the supraorbital torus is one continuous transverse supraorbital bar of bone, so unified that it is impossible to demonstrate its component parts. The first steps in its pedomorphism is the slight atrophy of the mass, revealing the nature of its tripartite composition, the condition seen in the Florisbad skull and the skull of the modern Australian aborigine. In later types, the lateral supraorbital margin becomes refined, leaving the supraorbital region with only the raised glabellar margin and the prominent supraciliary eminences as evidence of the strong torus man once had. This is the nature of the Boskop skull. As the pedomorphic process advanced, even these dwindled, leaving the smooth forehead of the Bush physical type, the almost perfect foetal condition. That such is the possible nature of the process seems to receive corroboration from the fact that, among living races, all these varieties of supraorbital regions may be found, but I do not know of one skull which shows, for instance, a massive lateral superior orbital margin unassociated with a prominent glabellar region and superciliary eminences.

The function of the middle face may be regarded as twofold. It forms a strong supporting base for the mechanism of mastication and also transmits the weight of the anterior portion of the skull cap and its contents. It is composed of three pillars, one central, composed of the interorbital bony framework resting on the body of the maxillae through their intermediary nasal processes; two lateral, one on either side of the face, consisting of the external angular process of the frontal bone, the frontal process of the malar and the malar bone itself. These three support the supraorbital arch which was once the torus.

In primitive man, the incisor teeth, in addition to their function of breaking up food into small pieces, preparatory to molar grinding, were used as tools, i.e. they were intrinsic tools,

and were adjuncts to the hands for holding and tearing structures apart. For such functions a strong base was necessary, and in primitive man the muzzle is characterised by a deep prognathic alveolar maxillary margin for the firm anchorage of the teeth, and by the body of the maxilla extending upwards towards the malars as a strong flat plate of bone, capable of withstanding stresses and strains. Such strains and stresses were communicated from the malars to the base of the skull by the massive zygomatic arches.

As man became inventive, two processes were going on simultaneously. The teeth which had previously been liberated from the function of fighting weapons were once more used extrinsically. Even to-day the teeth are still used for functions other than masticatory. Watch anyone unravel a knot when tools are not available! The invention of more types of tools, however, more or less left the teeth free for mastication and they dwindled; at the same time the brain was increasing in size.

As a result of this, the alveolar margin became reduced as did the body of the maxilla. It became excavated; bone is built for strength and lightness, where strength is no longer required the bone atrophies for the sake of lightness. If such were the nature of the process the enlarging forebrain would be deprived of some of its support by this atrophy of the central pillar. To prevent this, it seems that its task was taken over by the lateral pillars. As a result, the malar bone changed from the insignificant bone of atrophic appearance of the pre-*Homo sapiens* types, to the prominent structure it is in the facial skeleton of modern man.

It will be seen, therefore, that at some palaeolithic stage in man's evolution, he developed inventiveness, exemplified by the increase of specialised techniques. Whether by diffusion or by parallelism, or both (theories which do not concern the fundamental argument), these types and their mode of manufacture spread all over the man-inhabited world, giving to all types a physical liberation which would result in a more foetalised type of skull, a more human type of skull; giving them the stimulus for cranial expansion and growth, thereby enabling them to cross the line in the diagram from *Homo* to *Homo sapiens*. Any type of *Homo* with this increase of tool-type could, therefore, by the biological nature of his being, be the ancestor of the *Homo sapiens* races.

Such a theory remains a theory until there is skeletal evidence to change it into fact. That such a hypothesis has not been voiced before, though it has been hinted at by Sollas (1910), may be due to the fact that in the great array of evidence of man's ancestry in Europe there is unfortunately no evidence of this intermediate stage between *Homo* and *Homo sapiens*, nor is it likely there will be, since it has been conceded by all students of prehistory in Europe that Europe was not a centre of evolution, but was peopled by successive waves of immigration. However, during the past decade, Africa has yielded sufficient

evidence to hint at, if not to prove, that such a thesis is actuality. It is with such discoveries and their interpretation that I shall concern myself in this address.

III—Terminology in South African Physical Anthropology.

Before attempting this, it will be necessary to give some explanation for the terminology which the Department of Anatomy in the University of the Witwatersrand has created for physical types in African physical anthropology. As Professor Dart pointed out at the "Symposium on Applicability of Terms with Ethnological or Linguistic Significance to Race," held by Section E of this Association last year, the aim of physical anthropology is to isolate the fundamental types of physical structure of which a population is composed. To achieve this, the physical anthropologist must name groups of prehistoric skulls from the earliest features they show, and not from similar, but later types, to which may have been attached a culture. Only when, and if, there happens to be evidence of a recognised culture of known origin associated with the skulls, can skulls be named after cultures, and even then, only with the greatest of caution. Because of this, it is impossible for the same terms in both physical and cultural anthropology to have identical meanings, since there can be no expectation that one type of culture can be limited to one type of skeleton. Culture diffuses much more rapidly than racial type! Further, it would be unreasonable to expect that the origins of particular cultures will be found to synchronise with the emergence of a new physical type.

We know now that the later physical history of man in South Africa has revolved around three main physical types, Boskop, Bush and Negro, however many sub-types there may have been. In a science as young as the science of physical anthropology is in South Africa, it has been expedient for us to define these fundamental types, and to refuse to become lost in a morass of cultural names whose physical anthropological make-up has never been defined and agreed on.

The correctness of recognising the tall, dark-skinned, ovoid-skulled, prognathous Negro as one of the fundamental South African physical types is universally recognised. Concerning the other types, Bush and Boskop, there has been divergence of opinion, more superficial than deep-seated, among physical anthropologists, and gross misunderstanding on the part of some cultural anthropologists.

The Bush physical type as defined by us represents the dwarf pedomorphic type of man, slender-boned, with a low pentagonoid skull of small absolute measurements, broad orthognathous face, and identifiable physical peculiarities in practically every bone of the skeleton. In the living, this Bush physical type is characterised by diminutive proportions, slight habit, light yellowish skin, steatopygia, and hair in sparse peppercorn tufts. It has been the opinion, not only of South African

investigators, but overseas authorities of such standing as Deniker (1926) and Hrdlička (1928), that this type is the basic one, not only of the true Bushman but also of the pastoral Hottentot, i.e. of the whole of the "yellow-skinned" group of Dr. Broom (1923).

Our use of the name "Bush" in this connection has been cavilled at by ethnologists, who have failed to grasp the basic concept that diverse culture may be practised by members of one racial stock. Alternative names have been proposed, but unfortunately those suggested by one group of ethnologists and linguists are scornfully rejected by another. The only one which appears permissible is "Khoisan." This, however, has already been employed in a different sense by cultural anthropologists, such as Seligman (1930) and Schapera (1930), to embrace the whole of the cultural groups termed Bushmen and Hottentots. Thus it is not synonymous with "Bush physical type," since the latter term is applied only to one, albeit the principal one, of the physical types found among the "Khoisan" peoples. For the physical anthropologist to adopt "Khoisan" as a synonym for "Bush physical type" would therefore create even worse confusion and deny the fundamental principle of the science of physical anthropology.

The term "Bush physical type," as distinct from "Bushman people," is hallowed by physical anthropological usage throughout the world. Its use to denote the physical type of which the Bushman people include the purest, least hybridised representatives, is exactly analogous to that of the term "Mongoloid physical type," usually abbreviated to "Mongoloid," for the type whose purest representatives are found among the Mongol peoples.

It is granted that, in addition to recent Negro intrusion, the Khoisan (or Bush-Hottentot) peoples include physical elements other than the Bush type, and that the presence of these other elements results in certain divergences of physical features such as have led some physical anthropologists at different times to distinguish the so-called "Hottentot," "Korana," and "Strandloper" types from the Bush type. The majority of these features, which are divergent from the Bush physical type, are approximations to that other fundamental physical type whose nature was first disclosed by the Boskop fossil. To such features we give the name "Boskopoid." *When using this term "Boskopoid," it must be realised that there is not the slightest suggestion of its having a chronological significance. Although Boskop man, as a living race and pure physical type, belongs to the Middle Stone Age, yet by hybridisation with later types, his physical characteristics have been handed on through these later types, long after the living race of Boskop man had died out. Our use of the term "Boskopoid," as applied to the persistence of this Middle Stone Age physical type in living African races, is analogous to Boule's (1923, p. 288)*

use of the term " Cro-Magnon " as applied to present-day types living in the South of France.

The Boskop physical type, as the name implies, is typified by the fossilised skull from Boskop in the Transvaal. To that type, if we are to be zoologically consistent, must also be assigned the pre-Bush Zitzikama skulls, the Middle Stone Age skulls of Matjes River, and, in our opinion, the skulls from Fish Hoek and Springbok Flats. The justification for regarding these remains as a homogeneous physical type I have demonstrated elsewhere.

It has already been remarked that among the Khoisan peoples many subjects diverge from the Bush physical type and approach the Boskop in such features as stature, massive bones, and size and shape of skull. From the standpoint of physical anthropology such intermediate types can be described as Bush-Boskop or Boskop-Bush, depending on which type predominates in the admixture.

The opinion has been expressed by some physical anthropologists that the Bush-Boskop type thus defined represents the " Hottentot " type, which is held to be distinguished by such features as tall stature, larger skull, and coarser bones. This identification is explicitly stated by Drennan (1936). Keith (1934) also makes it, though in a curiously inverted manner. Describing the skull M.R. 4 from Matjes River, whose practical identity with the original Boskop skull he constantly reiterates, he concludes that this is " merely a large Hottentot skull "; from the classificatory point of view he would have been more logical had he concluded that the "Hottentot" skulls from which he made his comparison, and which are apparently much more recent than the skull M.R. 4, were of reduced Boskop type, i.e. had he named the physical features of the historical later skulls from the earlier prehistoric type.

Further research may well prove that the Bush-Boskop type of skull is that most commonly found amongst the Hottentot cultural group. Even if this should be the case it would be inadvisable to speak of the " Hottentot physical type," for we know already that not all cultural Hottentots are of the Boskop-Bush type, but are of purer Bush type, while many Boskop-Bush individuals are known who are not culturally Hottentots. Such terms as Boskop-Bush and Bush-Boskop, having no cultural significance but being purely physical, are both correct and self-explanatory from the physical anthropological standpoint; they are certainly less confusing to the cultural anthropologist than the misuse (as he well may deem it) by the physical anthropologist of a term with a well-established cultural connotation.

The dwarf Bush type almost certainly arose from ancestors less dwarfed (less pedomorphic), and such ancestors must have been physically very close to the Boskop type. Indeed, they doubtless belonged to the Boskop, or at least to the proto-Boskop type; Bush and Boskop are, as Keith (1935) says, cousin types.

It has been suggested (Pycraft, 1925, and Keith, 1934) that local evolution occurred in South Africa from the Boskop type through intermediate stages to the Bush type. The evidence of the Zitzikama cave, with which that of Matjes River is in essential agreement, indicates, however, a very different course of events. The Bush type arrived on the scene, it appears, in an already evolved form and, intruding itself upon the previously established Boskop type, gave rise by hybridisation to the intermediate form. While some of the invading groups seem to have remained of relatively pure Bush type, others became extensively infiltrated with Boskop blood, and it is among these that there occur such remarkable reversions to the Boskop type as the now famous skull U.C.T. 80 of the anatomical collection of the University of Capetown, a modern skull reproducing practically every feature of the fossil specimens of Boskop, Zitzikama and Matjes River.

What then, it is frequently asked, are the physical features of this Boskop type? I have analysed all the Middle Stone Age skulls of South Africa as a group, i.e. the original Boskop, Zitzikama, Matjes River, Fish Hoek and Springbok Flats skulls, as well as the modern Boskop skulls, U.C.T. 80 of the Capetown University collection and the Kalomo fragments. The great similarities found in this group so outweigh the slight divergences that they must all be regarded as representing normal variants of the Boskop physical type. From this analysis I have drawn up a summary of the salient features of the skull of the Boskop physical type.

IV—The Boskop Skull.

The Boskop skull is a massively constructed skull of great dimensions (the maximum cranial length exceeding 190 mm., and frequently exceeding 200 mm.) and correspondingly great capacity (generally over 1,500 cc.). It is dolichocephalic, relatively low vaulted, and characteristically pentagonoid in form. Athough the Matjes River skulls overstep the lower limit of orthocephaly, only M.R. 4 is decidedly orthocephalic. However, in a study at present in process, I find that the South African native races show a marked disproportion between altitudinal index and auricular height index. Frequently, a skull which is in one group of the altitudinal index is in a higher group of the auricular height index. To bring the latter into line with the former, it seems necessary to multiply it by a factor of 0·85. If this applies to early skulls such as Matjes River, then all the Matjes River skulls except M.R. 4 become chamaecephalic From the diagrams, in the absence of any statement to the contrary, M.R. 1 has been concluded to be ortho-ovoid. It is quite possible, however, that this is an illusion such as occurs in the case of the Fish Hoek skull, and that foetal parietal bossing may actually be present, but masked by excessive breadth of the base of the skull.

The narrow frontal region (fronto-parietal index usually below 70) shows a median ridge (trigonism). Post-coronal and interparietal depressions are also common features. The glabella and superciliary eminences are always prominent, generally massively constructed and emphasised by an ophryonic groove. The forehead, low and usually vertical, or nearly so, curves into a flattened or very slightly arched vault, whose highest point is at, or just behind, the bregma. The posterior portion of the skull is widely wedge-shaped, due to a flat sloping parieto-occipital region, the prominent foetal occiput, and the flat or sigmoid, almost horizontal nuchal plane.

Laterally, the supra-asterionic region is usually more concave than flat, and is never convex. This is best exemplified when the skull is viewed in norma occipitalis. The parieto-temporal suture follows the primitive and juvenile depressed course, being horizontal or only slightly convex in its anterior portion, and descending very obliquely posteriorly to form a very wide angle (sometimes nearly 180°), with a rather extensive parieto-mastoid suture. Of those skulls in which the region of the temporo-sphenoid suture is preserved, only the Zitzikama skull shows no *mons temporo-sphenoidale*.

As in other races, extinct and living, of *Homo sapiens*, the size and shape of the mastoid processes are variable, but rarely, if ever, do they attain the relative proportions of a medium sized process in other races. This diminutive mastoid process necessitates the presence of a bold ridge for the attachment of the sterno-mastoid muscle, and an extensive area of attachment on the base of the skull for the digastric muscle. This area is continued far behind the posterior limits of the mastoid process, irrespective of size. In the Zitzikama skull, and in U.C.T. 80, the digastric area is limited medially by a ridge which corresponds to the deeply excavated groove on the interior of the skull of the sigmoid sinus. Above the mastoid process are a well-marked supramastoid groove and a definite, often massive, supramastoid crest, which curves rapidly upwards from the porionic region.

The tympanic plate of the temporal bone is proportionately thin, and the articular surface of the broad shallow glenoid cavity extends backwards on to it; the articular tubercle is flattened while the post-glenoid tubercle usually forms a low blunt ridge. In partial correlation with this, the petro-tympanic fissure is exposed as a groove in the centre of the floor of the glenoid fossa, instead of being concealed at the junction of the floor and posterior walls. The root of the zygomatic process is very thick.

The inferior frontal eminence is usually present, though less accentuated than in the skull of the Bush physical type, and is frequently masked by the low-set and prominent anterior extremity of the superior temporal line. This line turns by a sharp flexure to form the posterior border of the external angular

process. The external angular process itself is usually triangular, deeply excavated, and projects markedly laterally, so that the minimum frontal diameter is usually ninety per cent. or less of the external biorbital diameter. Grooves for the branches of the supraorbital nerve are a common feature.

The face is short and broad, giving an upper facial index of about 50, and is massively constructed. Except for the Fish Hoek skull, which is slightly prognathous, the face is definitely orthognathous. In correlation with the shortness of the face, the orbits are low (index about 75); they are rectangular, with their axes directed obliquely downwards and backwards, so that a great deal of the medial wall is visible in norma lateralis. In the Fish Hoek skull a notch in the inferior border gives a pentagonoid outline to the orbit. The orbital margins are massive, the upper usually everted, and often ending in an external angular tuberosity such as is present also in the Australian skull, while infero-laterally the "orbital shelf" of Keith is a constant feature. The interorbital region is flat and inset; the nasal bones flat or slightly arched; and the nasal aperture low and broad. The subnasal region is short and there is no excess of subnasal prognathism.

Excavation of the infraorbital process of the maxilla is a feature of *Homo sapiens*. In the Boskop group, however, such excavation is frequently only very slightly marked. The true canine fossa in the premolar region of the alveolar process of the maxilla is also poorly marked or even absent. The surface of the body of the malar bons faces directly laterally, and has an upward tilt. It may be a plane surface or have a vertical convexity. The infraorbital process forms a very definite sharp angle with this surface, giving the Boskop facial skeleton a characteristic appearance.

The palate is large, shallow and rugose, with a strong median torus, while the dental arcade is either horseshoe-shaped (molar convergence), or has the shape of a truncated V due to the incisors being set in a straight line. The width of the foramen magnum approaches its length; it shows the variety of shapes seen in all races, but the occipital condyles never encroach upon its area. These condyles have their articular surfaces boldly convex in both diameters, and face as much laterally as inferiorly.

The interior of the cranium is characterised by a prominent massive *crista frontalis interna*, while the grooves for the middle meningeal artery and its branches, as well as for the sigmoid portion of the transverse sinus, are prominent and deep.

V—Boskop Man in East Africa.

Of recent years one of the most important discoveries in the prehistory of man has been that of Leakey in East Africa. In 1932, working in East Africa on the southern shores of the Gulf

of Kavirondo of Victoria Nyanza, Leakey found small fragments of a mandible at Kanam, which he placed in Lower Pleistocene; fragments of several skulls at Kanjera assigned to a Middle Pleistocene horizon; while earlier, in 1929, he found Late Pleistocene skulls at Gamble's Cave near Lake Elementeita in the Great Rift Valley. The geological horizons of the Kanam and Kanjera finds, however, have since been challenged and disproved, so that now no geological date can be put on this material. All that can be said of it is, that it is heavily fossilised and presumably of considerable antiquity.

The Kanam fragment is far too small to base any racial arguments upon, let alone to proclaim it the ancestral type of *Homo sapiens*. The chin region with its central mental tuberosity and lack of lateral mental tubercles is a type of chin which can be matched in fossilised mandibles in South Africa, and which we are inclined to regard as a normal variant of the Boskop type of mandible.

The Kanjera material, though fragmentary, is important. Leakey has reconstructed two of the skulls (K. I and K. III), and from his own description supplemented by evidence from the casts, sufficient evidence can be gathered to place these skulls fairly accurately.

Both skulls are of excessive length and great thickness of bone, and both are chamaepentagonoid. K. I is slightly trigonocephalic, both show interparietal flattening (interrupted by a median sutural ridge), while the postcoronal region of K. III is definitely flattened. The occiput is foetal in type in K. I and infantile in K. III In both, the forehead is low and slightly receding, the vault is a very low convexity, curving into a very flattened parieto-occipital region terminated by the prominent occiput, while the nuchal plane of K. III is sigmoid. K. III shows a large interparietal bone, a feature of the three newly discovered *Sinanthropus* skulls.

Both skulls show evidence of supra-asterionic flattening. The superior temporal line has a low set course and ends anteriorly as the lateral margin of a widely triangular, excavated, external angular process (K. III), which projects markedly laterally. The infantile nature of the glabella and superciliary eminences of K. I masks a certain degree of bilateral ophryonic grooving. From a fragment of the malar region, Leaky infers that the face of this skull must have been relatively small and that some degree of infraorbital excavation was present.

The interior of the skull K. I reveals a prominent *crista frontalis interna*, while K. III presents deeply excavated vascular grooves of the middle meningeal vessels.

Elliot Smith's analysis of the endocranial cast shows that the fullness of the anterior extremities of the frontal lobes, which he stressed in his description of the original Boskop cast, is present in the case of K. I, and summarises his findings thus,

"to sum up, there are definite indications that the brain of Kanjera man reveals extremely primitive features in association with traits that are distinctive of the species *sapiens*," a statement which would serve equally well for a summary of the description given by him of the Boskop endocranial cast.

This interpretation by Elliot Smith of the endocranial cast, coupled with the foregoing salient features of these skulls, reveals that the Kanjera remains, heavily fossilised and of great antiquity, belong indubitably to the Boskop type and may represent a form earlier than the original Boskop skull.

This primitive Boskop type must have persisted in a pure state for a long time in East Africa, for it is only during the Late Pleistocene that this type is found to be mingled and hybridised with others. The Gamble's Cave skulls are a very raw unharmonious blend of physical features of this ancient Boskop type with those of later Caucasoid and negroid types. The same mixed type occurs at a later (Mesolithic) date in the Elementeita skulls.

The Boskop features of this Upper Aurignacian people of East Africa, as seen in Gamble's Cave 4*, are the elongated pentagonoid, slightly trigonoid norma verticalis; the relatively low vault, whose highest point is at bregma; the wedge-shaped parieto-occipital region with interparietal flattening; the foetal occiput and sigmoid nuchal plane; the small mastoid processes leaving exposed the posterior end of the digastric fossa; the presence of a sternomastoid ridge and the bold upward curvature of the supramastoid crest; the horizontal parieto-temporal suture; the orthognathism; the slightly excavated infraorbital depression, with an inflated appearance; the orbital shelf and the upward tilt of the malar bone.

In Gamble's Cave 5, the Boskop features are less evident, but its Boskop parentage is revealed by its chamaepentagonoid cranial form; the low forehead and flattened vault; the sloping parieto-occipital region; the sigmoid nuchal plane; the presence of an inferior frontal eminence; the course of the parieto-temporal suture; the orthognathism and the presence of an orbital shelf.

In Gamble's Cave 4, there are features foreign to the Boskop type; the size of the orbits, the slightly arched nasal bones, the relatively long and narrow nose, the elongation of the subnasal region and the depth of the palate. In addition to these, there are present in Gamble's Cave 5, the following non-Boskop features: the post-porionic situation of the vertex, the reduced prominence of the occiput, the horizontal course of the supramastoid crest and the subnasal prognathism. In this skull, as

* The description of the features of the Gamble's Cave material and of the Elementeita material has been obtained from Dr. Leakey's "The Stone Age Races of Kenya" and my own observations on casts of some of these skulls in the Coryndon Memorial Museum, Nairobi.

compared with the previous one, the increased height of the orbits is more marked in that they are almost circular, the narrowing of the nasal aperture is even more accentuated and there is general greater elongation of the face.

The same mixed physical type of the Gamble's Cave skulls is apparently present also in the Oldowai skeleton, whose age, so long a matter of dispute, is now established as the upper Kenyan Aurignacian. The skeleton is thus approximately contemporary with the Gamble's Cave skeletons which it resembles in its physical constitution.

VI—The Asselar Skeleton.

A possible connection between the fossil types of South and East Africa and those of Europe has been seen in the skeleton from Asselar in the Southern Sahara, some two hundred and fifty miles north-east of Timbuctu. This completely fossilised skeleton belongs to a period when the Southern Sahara was a fertile region inhabited by Upper Palaeolithic man, with a fauna of gazelles, antelopes and warthogs, while crocodiles and fish flourished in the now long dried-up rivers.

The Asselar skeleton is characterised by a long skull (193 mm.) with a minimum cranial capacity of 1,500 cc., massively built. and associated with other skeletal parts of the same massiveness. The photographs of the skull, published in the magnificent monograph of Professors M. Boule and H. Vallois (1932), immediately suggest Boskop affinities, or at least a Boskop leaning. A detailed study of the description and illustrations reveals that while many features of the skull are foreign to the Boskop type, many others have their definite counterpart in the Boskop skulls of South Africa.

The vault is ortho-ovoid, and in the norma verticalis presents none of the characteristics of the Boskop features. In norma lateralis, however, it suggest affinities to the Boskop type by the very slight degree of total prognathism, the prominent, though slender, supraciliary eminences, the presence of an ophryonic groove, the low vertical forehead, the wedge-shaped nature of the parieto-occipital region, the prominent occiput and sigmoid nuchal plane. It departs from the Boskop contour in having a post-porionic vertex, and in the marked degree of sub-nasal prognathism.

The supra-asterionic region shows Boskop concavity, while the temporal bone is definitely Boskop in all its features, except for the absence of the sternomastoid ridge and the slenderness of the boldly upcurved supramastoid crest.

In norma facialis, the general aspect is that of the Boskop type, except for the elongation of the face and the ridging of the narrow nasal bones. The depth and smoothness of the palate are foreign to the Boskop type. The vascular impressions on the internal aspect of the skull are Boskop in their definiteness.

In their discussion of this skeleton, the authors were limited by having available only the earlier literature relating to the Boskop type in South Africa, since their comprehensive work, the most complete survey of South African physical anthropology attempted by any overseas worker was published in 1932. Since, during the past few years, a considerably greater knowledge of the features of the Boskop type has been accumulated, it is permissible, therefore, for us to reconsider and restate the conclusions of these authors.

Their final conclusion is that Asselar man is more akin to the modern South African Negro and to the " Hottentot " than to any more northerly African type. He represents, in their opinion, a primitive Negro stock, from which diverged, on the one hand, the Bush-Hottentot group on the other, the true Negro group. To these eminent French scholars, the Bushman and West African Negro represent the extremes of differentiation, while the " Hottentot " and the Bantu-speaking Negro of South Africa are less removed from the original ancestral type. Since they regard the Boskop group of fossils as representing a stage in the evolution of the Bushman type from the primitive Negro stock they seem tacitly to recognise the close approximation of the Boskop and " Hottentot " types to the Asselar man.

The conception of a " Hottentot " held by these authors is that it is a type less differentiated from the primitive Negro stock than are the typical Bushmen. Since they regard the Boskop group as intermediate between the primitive negroids and the modern Bush type, their views seem to involve a close approximation of the " Hottentot " and Boskop types. As has already been stated, this " Hottentot " type has now been shown to be fundamentally the Bush physical type with the incorporation of many Boskop features. From this, then, it can be inferred, in the light of our conception of African physical types, that the diagnosis of the Asselar skeleton made by Professors Boule and Vallois is not at variance with mine, which is that Asselar man is a Boskop type containing features of another intrusive strain.

This intrusive strain in the Asselar skull is similar to that seen in the Gamble's Cave and Oldowai material. It is characterised by an ovoid cranial form, increased height of vault, elongation of the face with a tendency to prognathism, increase in height of orbits, decreased nasal breadth, and increased depth of palate. These intrusive features are wholly foreign to the primitive African stock represented by the Boskop skulls of South and East Africa, and are more manifest in those skulls from Gamble's Cave than in the skull of Asselar man.

The Gamble's Cave skulls do not represent a new type, for all the evidence points to hybridisation. The elongated face superimposed on an elongated pentagonoid pedomorphic braincase shows such a lack of biological harmony that it is hard to conceive of the concatenation of two such features resulting from any cause other than hybridisation. It seems impossible, and

there is no skeletal evidence in Africa to prove it, that the Kanjera Boskop type, already destined to a pedomorphic fate, could retrace its evolutionary steps and evolve into a type with an elongated, salient, gerontomorphic face.

The presence of this exotic strain in both the Asselar and Gamble's Cave skulls is the more significant since both are of similar geological age, dating from a major pluvial phase of the Upper Pleistocene. Apparently contemporaneously there lived a Boskop type in Africa and a primitive type in the Near East, from which probably emerged the Caucasian races in Europe, and it is a fair conjecture that the fertile areas of Northern Africa also attracted them. Shanklin (1936) has speculated that this primitive type is most nearly represented to-day by the long-skulled, long-faced, serologically primitive Bedouins of Northern Arabia and the Rif peoples of Northern Africa. Entering this region they would encounter the Boskop peoples already established in this continent, and such a mingling probably accounts for the mixed physical type seen in the Asselar and Gamble's Cave skulls.

The Bush physical type, however, is not as Boule and Vallois suggest, a derivative of this hybrid northern African stock. It must have branched off at some remote time from the early Boskop or even proto-Boskop type, and, remaining relatively pure in the central eastern part of Africa, was able to continue in its course of progressive pedomorphism, without the disturbance produced by intrusive strains, before it commenced its southward migrations. Later, however, it seems possible that some of the offspring of the hybridised northern people mingled with their pure-blooded and more southern relatives. By such a mingling of primitive Boskop and Near East hybrid types with relatively pure Bush types, may have arisen the variant of the hybrid Bush physical type sometimes called "Hottentot." This variant would bring with him modified Boskop elements to reinforce and accentuate the Boskop heritage of his Bush forebears. Thus his physical features come to be those which we designate by the terms Bush-Boskop and Boskop-Bush. To this may be also added the Near Eastern primitive strain which produces the physical features vaguely termed "Hamitic," as well as the evidence of affinities with the Near East as shown by his blood groups. (Elsdon-Dew, 1936.)

VII—The Australoid Complex in South African Physical Types.

As collections of prehistoric South African skulls grow, a type of skull sporadically appears which has a raised glabellar region, and prominent supraciliary eminences which give the nasion an inset appearance. This type was first noted by Broom in 1923 in a series of relatively recent skulls assigned to the Korana group, at a time when only two ancient African skulls were described the original Boskop and Broken Hill skulls. In

1926, Allen described an Australoid skull from Mistkraal which was fossilised and clearly of some antiquity. In describing this skull he noted that apart from excessive development of the *medial* supraorbital region, it possessed several features in common with the original Boskop and Zitzikama skulls. In 1929, Broom reported another ancient skull with Australoid features in the supraorbital region from Barkly West, while Wells found a further example in the Zuurberg collection. This Zuurberg Australoid showed, in addition to massive supraciliary development and primitive features in the parietes, several Neanderthal reminiscences in the lower extremity. Also, in the same year, Drennan described the Cape Flats skull, heavily fossilised and possibly associated with a Middle Stone Age industry, which seemed to clinch the evidence of an Australoid strain in South African races.

When Broom first suggested the possibility of this Australoid element, he said that " it may seem a little premature to speak of a South African Australoid race before one is in a position ' to deliver the goods.' " It is my task to review all the claimants to the Australoid type to see whether the " goods have in fact been delivered."

The Cape Flats skull shows all the elements of the other so-called Australoid skulls. Because of this, and because it is one of the most complete and probably the most ancient of all, I will use it as the type specimen. As the face is very fragmentary and has been described by Drennan as having European and Negro characteristics, it can therefore be omitted from the argument. The claims of this skull to be Australoid rest largely on the supraorbital region. In the Cape Flats skull, the right supraciliary eminence is massively projecting, apparently impacting into what was probably a raised low-set glabella. Laterally it fades rapidly to disappear in the lateral third of the supraorbital region, where it is replaced by the flattened area of the supraorbital triangle whose inferior margin, i.e. the lateral third of the superior orbital margin is of Boskopoid thickness but sharp-edged. This supraorbital complex receives an exaggerated prominence from the well marked ophryonic groove. These features are found to an even more marked degree in the Mistkraal and Zuurberg skulls.

On the other hand, in the typical Australian skull, there is no ophryonic grooving to accentuate the prominence of the supraorbital region. The absence of the ophryonic groove is regarded by Sollas (1908) as pathognomonic of the Australian skull. The medial supraorbital region agrees with that of the Cape Flats skull, but the lateral region differs markedly. The supraciliary eminence is terminated by a groove passing upwards and lateralwards, commencing at the supraorbital notch for the supraorbital nerve. Lateral to this groove the lateral portion of the supraorbital margin is a massive, blunt, rounded, everted flange of bone which terminates in the lateral tubercle, which is also the

lateral extremity of the external angular process. This portion is of such dimensions that medially it seems to flow into the supraciliary eminence, but the two elements are distinct and do not produce, even in miniature, the uniform torus of the Neanderthal type. (Cunningham, 1909.) As such, it forms a close resemblance to the supraorbital torus of the Florisbad skull.

If we submit the Cape Flats to the criteria of Krogman (1932), it is seen that this skull compares very poorly with the Australian skull. Krogman, after analysing over a hundred Australian skulls, came to the following conclusion:—

> " The facial view of a mental-composite male Australian (which is really what an average or type amounts to) may be analysed in an attempt to set forth those features conceding to the definition of 'primitive.' Were I to set down, in order, the four features which struck me as outstanding, I should write: (1) Size and rectangularity of orbits and massiveness of brow; (2) width and relative slightness of middle face; (3) size of palatal arch and teeth; (4) narrowness of frontal portion of vault. Let us, therefore, consider these in some detail.
>
> " The mass impression of the orbital apertures is imparted by the term 'cavernous.' They seem very large for the face and are pronouncedly angular with a horizontal (so-called, but generally slightly oblique) axis the longest. They are surmounted by massive, 'frowning' brow ridges which continue across the median plane and laterally contribute to an unusual degree to the lateral margin of the orbits. The impression of relative smallness of size is further enhanced by a narrow interorbital breadth.
>
> " The middle face. comprising the narial aperture and malar arches, is quite wide, but tends to be rather slight in proportion. As a rule the arches project laterally well beyond the cranial contour, but this does not suffice to give them prominence in the sense that a Mongoloid or Eskimoid 'high cheek bone' would. They are imprisoned and dwarfed, as it were, between the large palate and massive orbito-supra-orbital complex. The middle face further gives the impression of slightness due to the large piriform narial aperture with its guttering margins and slender nasal bones.
>
> " The lower portion of the face seems to be 'all teeth and arch,' for the palate and teeth of the Australian are second only to the Tasmanian in actual and relative proportions. The size is accompanied by subnasal prognathism which thrusts the palate markedly forward. Again, therefore, we find an area which minimises the middle portion of the face and which stands out as a very definite morphological feature.
>
> " The massiveness of the upper face receives its crowning touch, literally, by a marked narrowness of the frontal

portion of the vault. which seems to slope away from the face. This is due to the strongly developed linea temporalis which sweeps up and back, compressing the skull antero-laterally, so that in approximately 40 per cent. of the skulls the minimum frontal diameter is found near the intersection of the linea temporalis with the coronal suture.

" Apart from the face, the long, narrow, moderately high cranium, with pronounced occipital development (so that the post-porionic length is the greater) seems to be characteristic if not actually definitive. The mastoid is porportionately small, but all muscular impressions are very wel marked, especially in the occipital bone.

" So much for this summary. Were *all* of the traits enumerated to be found in the same skull, the inference of identity with, or kinship to, the Australian type would be justified. The real problem, however, arises when one or more are found associated with other features. The issue then becomes one of possible influence, either from a common precursor or through actual contact. But, if the several characters mentioned *are* primitive, they may occur sporadically as an indication of a remote common heritage. Again, there is no reason, so far as is known, why any given essential human morphological trait may not occur at random as a mere expression of the range of human variation."

Owing to the salient morphological difference of the lateral supraorbital region, which prevents any real comparison between the Cape Flats skull and the Australian aboriginal skull, and because this skull falls far short of Krogman's criteria, if the term Australoid is to be used with reference to the Cape Flats skull it must be used with inverted commas. It, therefore, does not " deliver the goods," in the sense of indicating a racial element distinct from others already known in South Africa.

In skulls such as Cape Flats and the other " Australoid " South African types, we have a normal variant of the Boskop type superficially resembling the modern Australian aboriginal type. To me there is no doubt that the Florisbad type is the progenitor of the Boskop type, which by selective breeding changed from the ancestral type to this extravagantly pedomorphic anomaly. No matter how selective their breeding, ancestral genes must have been present in his make-up, and they manifest themselves in all South African native types by the sporadic appearance of " Australoid " skulls such as the Cape Flats skull of the Middle Stone Age, the Zuurberg skull of the Late Stone Age, and such modern examples as the Bayville skull and the modern Zulu skulls A. 250 and A. 437 of our Departmental collection.

So far, I have shown that there is in Africa a fossil type—the Boskop type—which at one time populated the south, east and north of Africa, and that later, by admixture with a foreign intrusive strain this type gave rise to most of our modern African

physical types. Having built up a fairly clear hypothesis of the forward movements from the time of the pure Boskop occupation of Africa, it may be illuminating to try to find evidence for the antecedents of this type.

VIII—The Florisbad Skull.

In 1932 Professor Dreyer unearthed at Florisbad, twenty miles north of Bloemfontein, the most important human fossil found in South Africa since the discovery of Rhodesian Man. The circumstances relating to this find are outlined in Professor Drennan's analysis of this skull and its endocranial cast (1937).

The first diagnosis of this skull was made by Professor Dreyer in 1935, when he described it "as a very primitive form related to *Homo sapiens*," and he tentatively placed it in a sub-genus of "*Africanthropus*." Kappers, at the same time, commenting on the endocranial cast, approximated it to fossil represenatives of *Homo sapiens*, but his interpretation, as Dreyer (1936) has pointed out, was vitiated by an incorrect orientation of the cast. In this latter paper, Dreyer concludes that, "the Florisbad skull belongs to the prehistoric South African race—the Bushman, of which he is a very early and very primitive representative." In this conclusion Dreyer appears tacitly to accept Kappers' view that the specimen is one within the limits of *Homo sapiens*.

On the other hand, Professor Drennan, in a brief communication to this Association in 1935, and in a more detailed study presented to the Royal Society of South Africa this year, has argued brilliantly in favour of the view that Florisbad Man is best interpreted as an African variant of the Neanderthal race. He adds as an afterthought, but without detailed demonstration, that "in Florisbad Man, Rhodesian Man and the Cape Flats Australoid we have a closely related phylogenetic sequence linking the *Homo primigenius* to the *Homo sapiens* type."

Both these diagnoses are correct as far as they go, and may be regarded as elucidating different facets of this most complicated skull. The outstanding features of the skull are its excessive absolute length (210 mm.?), and its thickness of bone, which seems to Professor Drennan to "cry out for a Neanderthal interpretation." Fossil skulls with such general features are already known in South Africa, and it is surprising that Professor Drennan turned his eyes to Europe for his diagnosis, and by doing so missed a possible diagnosis lying at hand under his eyes.

In my analysis of the Florisbad skull, by using the criteria of Cunningham (1909) and Sollas (1908) I have shown that the supraorbital torus of Florisbad Man, showing as it does its tripartite composition and unaccompanied by an ophryonic groove, is far removed from the Neanderthal type of torus, but is closely akin to that of the modern Australian aborigine. Again, the situation of nasion is Australian rather than Neanderthal.

The facial skeleton of the Florisbad skull, with its infra-orbital excavation, the bevelling of the infero-lateral angle, the laterally protuberant malar bone, the plane of whose body faces directly lateralwards, links this skull with *Homo sapiens*, and not with Neanderthal Man.

Again, in the endocranial cast there are features which prevent a Neanderthal interpretation. The evidence of both the frontal and parietal lobes indicates clearly that the brain of Florisbad Man was considerably different from, and less specialised than, that of Neanderthal Man. It presents a much closer parallel to the more generalised stage of human cerebral evolution represented by Rhodesian man. Its chief differences from that of Rhodesian Man lie in its greater size, and in the configuration of the frontal region, differences which suggest a condition characteristic of *Homo sapiens*. Thus interpreted, there is nothing to negative the possibility of the Florisbad endocranial cast being the precursor of the Boskop type, the latter being only distinguished by a greater degree of expansion in the parietal and inferior pre-frontal regions.

When we look for types which can be related to the Florisbad skull, it is necessary to compose it with Neanderthal and Rhodesian Man on the one hand, and with the Boskop type and the Australian aboriginal on the other, since in my analysis I have hinted at a proto-Australian diagnosis for the Florisbad skull. While the skull of Florisbad Man agrees metrically with that of Neanderthal Man, as Professor Drennan has shown, there is no agreement non-metrically. The nature of the endocranial cast is such that Florisbad Man must have been a more generalised being that Neanderthal Man. Because of this, I can see no close phylogenetic relationship between Florisbad Man and Neanderthal Man.

Rhodesian Man is just as dissimilar in norma facialis from Florisbad Man as is the Neanderthal type, but there is a much closer agreement between their endocranial casts, which, I think, warrants the claim of relationship between the Rhodesian type and the Florisbad type.

A comparison of the non-metrical features of the Florisbad skull with those of the Australian and Boskop skulls is revealing. Every feature of the Florisbad skull is paralleled in one or the other, and often in both of these two latter types, to such an extent that one is forced to the conclusion that there is a filial relationship between the Australian and Boskop types and the Florisbad type. That the Australian skull seems nearer to the Florisbad skull than is the Boskop, is due to the gerontomorphic nature of the Australian type as against the pedomorphic nature of Boskop Man.

It seems a long stretch of imagination to link an extinct African type with a living Australian type, but the sporadic appearance of "Australoid" elements in South African types

and the similarities between the proto-Australian Wadjak skull and the Florisbad and Boskop types clearly show the link.

IX—The Relationships Between Ancient Types of Africa and the Orient.

For some time now I have been struck by the fact that features which have been considered specific to the pre-Negro populations of Southern Africa are to be seen in such widely separated ancient types as Rhodesian Man and *Sinanthropus*. The implications of these observations have been strengthened by two recent publications by Leakey (1937) and by Dubois (1937). Dubois finds marked and striking resemblances between *Homo soloensis* (a type regarded in the direct line of evolution from Sinanthropus to modern Oriental types) and Rhodesian Man; while Leakey reports on a skull from Lake Eyassi in Tanganyika with definite Sinanthropic characteristics. If the Sinanthropic type is known in Africa, and if Rhodesian Man and *Homo soloensis* are so strikingly alike, then there should be resemblances, and close ones, between Rhodesian Man and *Sinanthropus*. Comparison of the skull casts and endocranial casts of these two reveal such similarities.

Both are in comparative agreement in essential calvarial indices. On normal verticalis both are seen to have foetal parietal bossing. Because of the lowness of the skull, concomitant on the lack of development of the superior parietal region of the brain, the parietal bones are almost wholly concerned in the formation of the roof of the skull and take little part in forming the lateral walls. This being so, the parietal bosses lie in norma verticalis and not at the junction of the norma verticalis and norma lateralis as in modern skulls. Hence cranial form (by Frassetto methods) cannot be estimated. Foetal parietal bossing gives a pentagonoid contour to the norma verticalis only in recent skulls.

The supraorbital torus of both is alike, except that in Rhodesian Man there is already a reduction of the medial part of the superior orbital margin. In both, the frontal region is narrow and shows well-marked trigonism; post-coronal flattening is present, although more marked in Rhodesian Man.

On norma lateralis the cranial contours are in agreement, although that of Rhodesian Man is larger in all diameters. Superimposition of tracings showed that the parieto-occipital and parietal contours are similar, although the contours of the frontal region and the nuchal plane differ. The frontal region in Rhodesian Man is an inclined plane, whereas in *Sinanthropus* it is a wide arc, due to the salient ophryonic groove, which is even more accentuated in the newly discovered adult skulls. The nuchal plane in Rhodesian Man is flat and almost horizontal, and terminates in a massive torus occipitalis. In *Sinanthropus* it is slightly convex with a much less prominent torus occipitalis.

If, however, the massive torus occipitalis of Rhodesian Man is neglected, the contours of the two nuchal planes are in essential agreement.

The temporal bones of both are very similar. The mastoid process in each is small and mamillated in shape, leaving the digastric fossa exposed posteriorly. The lateral aspects of the mastoid region coincide in appearance so much that either skull, from the nature of the temporal bone, could well be the ancestor of Boskop Man. The glenoid cavities are elongate, narrow, and of medium depth, although the post-glenoid tubercle of Rhodesian Man is more developed than that of *Sinanthropus*. The specific *mons temporo-sphenoidale* of the Bush physical type is diagrammatic in both Rhodesian Man and *Sinanthropus*.

When it is remembered that Rhodesian Man is a fully developed adult and *Sinanthropus* only an adolescent (Davidson Black, 1931), the resemblances become more marked since some of the apparent differences might well be due to the increased muscular development of mature adulthood.

A comparison of the analyses of the endocranial casts of Rhodesian Man (Elliot Smith) and *Sinanthropus* (Elliot Smith and Shellshear) show that, while *Sinanthropus* has a more generalised cerebral pattern, there are features common to both of sufficient importance to allow of a postulation of relationship.

Emphasis has been made by Weidenreich (1937) on the generalised nature of *Sinanthropus*. Rhodesian Man may therefore be taken as a more specialised later type, but definitely related to *Sinanthropus*.

Rhodesian Man has been regarded enigmatically in physical anthropology because of the confusion arising out of the absence of real authentic knowledge regarding his geological horizon. Important as such a point is, it matters little in assessing the place of the Rhodesian Man *type* among other fossil types. If the Broken Hill skull is recent, then it must represent a more ancient type which has persisted up to such a recent date. It means that this Rhodesian Man *type* existed in Africa long before this actual specimen did. How far back this type goes is the only point in doubt. The evidence of Leakey's Lake Eyassi skull of Gamblian date, the marked similarities of Solo Man and Rhodesian Man, the similarities between Rhodesian Man and Pekin Man all point to one main fact, that in Africa there was a definite Sinanthropic stock, retaining its essential Sinanthropic features as late as the Gamblian pluviations, i.e. the latter half of the Pleistocene.

X—The Evidence of Endocranial Casts.

The late Sir Grafton Elliot Smith and his pupil, Professor Shellshear, in a long series of studies, have traced the evolution of the brain from ape to man, as shown by both endocranial casts from fossil skulls and by brains of primitive living races. Their

work has made clear the steps by which the great expansion of the association areas of the pre-frontal and parieto-temporal region of the brain, which distinguishes the human from the simian type of cerebral organisation has been brought about. They have shown that in the parieto-temporal region, expansion first takes place in the posterior portion of the middle temporal convolution, and in the supramarginal area which surrounds the posterior extremity of the great lateral or Sylvian fissure. In the pre-frontal region, it is the inferior frontal and fronto-orbital areas lying just above the orbital margin which first undergo expansion. From these centres the process of expansion gradually extends throughout the association areas. Further, the sequence in which the various territories undergo this expansion in the course of evolution is the same as that in which they attain full functional development in the growth of the brain of the modern human child.

As a result of these studies by Elliot Smith and Shellshear, it is possible, by an examination of the relative expansion of the different portions of a human brain or endocranial cast to assess, with reasonable accuracy, its position in the ascending scale of brain development.

Shellshear and Elliot Smith (1934) conclude "that the endocranial cast of *Sinanthropus* reveals a type of brain which fulfils all the requirements which make it the ideal generalised type from which the brains of all the known varieties of fossil and modern man have been derived. . . . The Rhodesian cast shows striking inequalities in the fullness of the cortical areas brought into prominence by the process of expansion which affects certain other areas, and on this subject one of us (G.E.S.) wrote: 'Hence there is revealed in the Rhodesian cast a much more striking demonstration of the development of the cerebral hemisphere that is going on within the human family than in any other cast.' This is no longer the case, for the cast of *Sinanthropus* shows the earlier stage even more clearly than does the cast of *H. Rhodesiensis*. . . . In other words the evidence shows that the cast of *Sinanthropus* is unspecialised; that it fulfils all conditions which permit us to state that it could give rise to all those types of human brain.'

In the same memoir the authors remark: "We are therefore of the opinion that the endrocranial cast of the brain of *Sinanthropus* is more primitive and in an earlier stage of evolution than that of *Pithecanthropus;* that the conditions found in *Pithecanthropus* must have been derived from a generalised type. Further, their essential similarity is so marked and they are so closely related that this type was probably *Sinanthropus.*" This surprising, and at first sight, paradoxical conclusion has recently received support from the observations of Weidenreich (1937) on the newly discovered skulls of *Sinanthropus*.

Regarding *Homo soloensis*, Kappers (1936) has concluded that the endocranial cast of this form is less developed than those

of the Neanderthal and Rhodesian types, and in many respects closely similar to that of *Sinanthropus*, though in a number of features it is more evolved than that type.

Elliot Smith (1928), in discussing the endocranial cast of Rhodesian Man, after making the statement already quoted, continues: "The interest of this condition is enhanced by the fact that the parts of the brain which reveal the most striking contrast in size when the human brain is compared with the anthropoid ape, are those which reveal the most striking deficiencies in the Rhodesian cast, and in the second place, these same areas attain their full maturity latest in the process of development of the brain of the modern human child. . . . The general contour of the brain and the peculiarities of its form and proportions suggest the kinship of Rhodesian Man with the Neanderthal species. The great deficiencies in development of the pre-frontal, upper parietal and inferior temporal areas, however, clearly differentiate it from the Neanderthal type, and reveal a condition definitely more primitive."

From every detail of Elliot Smith's description, it is clear that the Rhodesian cast, while it may have been ancestral to the Neanderthal type, is equally capable of being the precursor of such primitive modern human brains as those of the Australian aboriginal and the South African Bushman.

The evidence of the endocranial cast of the Florisbad skull reveals that this type presents a close resemblance to the generalised stage of human cerebral evolution represented by Rhodesian Man. Its chief differences from that of Rhodesian Man lie in its greater size, and in the configuration of the frontal region, differences which suggest a condition characteristic of *Homo sapiens*.

The probability that the Rhodesian type of brain was directly ancestral to the modern is therefore strengthened by the evidence of the Florisbad cast, and receives further corroboration when we consider the endocranial cast of skulls of the Boskop group.

Of these, that of the original Boskop skull has been described by Elliot Smith (1918). Endocranial casts were prepared by Professor Dart from the Zitzikama fragments, and some of the salient features revealed by them are noted in his paper (1923), but these important specimens have not yet received the detailed publication which they deserve. I have been privileged, however, to examine them, and incorporate my observations with this review. In addition, Meiring (1936) has given an elaborate description of the features of the frontal region in the endocranial cast of the oldest Matjes River skull (M.R. 1), but no account of the other features of the brain in these skulls has been published. Comparison of the casts from the Boskop and Zitzikama fragments shows agreement wherever the fragments overlap, i.e. these remains are homogeneous in their endocranial features.

In spite of their very much greater size, they reveal a remarkable series of similarities to the Rhodesian cast. In common with that cast they present a striking lack of development of the upper part of the pre-frontal region, a widely open temporo-cerebellar fossa (as in *Sinanthropus* and Rhodesian Man), bespeaking the poor development of the inferior temporal region, and the marked parieto-occipital depression which gives to the occipital poles the appearance of an excrescence upon the cast. This last feature, as Shellshear and Elliot Smith have pointed out, is shared not only by *Sinanthropus* and Rhodesian Man, but among living types by the Australian aboriginal.

In only two regions of the cortex does the Boskop type of cast show significant advance over the Rhodesian type. The first of these is in the area of the parietal eminence in the supra-marginal region, the territory in which, as Shellshear and Elliot Smith have reiterated, the most significant expansion of the parietal cortex occurs It is the progress of this expansion which has determined the difference in the setting of the parietal bones between Rhodesan Man and Boskop Man. The eminence is, however, still circumscribed by depressed areas both superiorly and laterally. The other area of expansion is the inferior frontal; it is, as a result of this, that as Elliot Smith says: " The frontal poles present the ample rounded form that is distinctive of the cranial cast of *Homo sapiens*." The extent of this expansion, however, is considerably less in the Boskop type than in the Bushman, a feature also demonstrated for the Matjes River specimens by the detailed analysis of Meiring.

It is, therefore, not surprising that Elliot Smith, writing before the Rhodesian and Pekin specimens were known, stated that the Boskop endocranial cast "probably represents the earliest (not necessarily in actual age) known phase of *Homo sapiens* in the course of his transformation from a condition analogous to that of Neanderthal Man." These more recent discoveries entitle us to consider that it was from the condition represented by Rhodesian Man that the transformation revealed by the Boskop type took place.

There is nothing to negative the possibility of the Florisbad endocranial cast being the precursor of the Boskop type, the latter being only distinguished by a greater degree of expansion in the parietal and inferior pre-frontal regions.

A further stage in the transformation from Rhodesian Man to modern types is represented by the Bushman. Shellshear and Elliot Smith have declared that " it appears to us that from the known brains of Bushmen, this race shows a greater assemblage of primitive features than is to be found in other races." Meiring has demonstrated that the features of the frontal region of the Bushman form an exactly intermediate type between those of the Boskop type and of the European. In studies now in progress in our own department by Mr. Wells, to whom I am

indebted for a great deal of this analysis of endocranial casts, it is indicated that in practically every feature the brain of the Bushman takes up an intermediate position between the modern European and such primitive types as *Sinanthropus* and Rhodesian Man.

CONCLUSION.

During the last two decades, then, South Africa has revealed an amazing series of human fossil remains. First, in antiquity of type, there is the Neanderthal type represented by Rhodesian Man with its close affinities to the ancient fossils from the Orient, *Sinanthropus* and *Homo soloensis*. In the *Sinanthropus* type, Weidenreich sees the origins of the Mongoloid races. Next comes the Florisbad skull, with its definitely *Homo sapiens* features, but showing similarities in its endocranial cast with that of Rhodesian Man (the only divergences being those of specialisation), and having a type of facial skeleton which could have evolved from that of Rhodesian Man, if my theories of facial evolution are tenable.

Later in the time sequence, and in antiquity of type, we have Boskop Man and his associated "Australoid" type, showing a homogeneity of features such as could only result from the logical pedomorphic evolution of the skeletal and cerebral traits of Florisbad Man. Following on his heels is the Bush physical type, a very old type, which has persisted up to to-day. His origins go far back to the beginnings of Boskop Man, his cousin type, each exploiting the pedomorphic biological mechanism. His threatened extinction, like that of Boskop Man, may be due to the lavish and too rapid shedding of some, as yet, essential gerontomorphic features, leaving him as mentally defenceless as his foetal frame leaves him physically. His variant, Bush-Boskop or "Hottentot" brother, with a more gerontomorphic strain in him physically, and maybe mentally, survived more successfully, until the Bantu-speaking Negro, a far superior fighting machine, subdued him, and incorporated him in his physical make-up.

It seems a far cry from the ancient Sinanthropic generalised type to our modern African types, just as it is from the modern Mongol back to *Sinanthropus* himself. The evidence which Weidenreich advances for his claim rests chiefly on the presence of the *torus mandibularis*, a swelling of varying degree on the inner sider of the lower jaw; the shovel-shaped appearance of the incisors, and the incidence of the interparietal bone, features common to both *Sinanthropus* and the modern Mongol.

Shovel-shaped incisors seem to be an almost constant feature of the Boskop physical type; it is a recurring feature in Bush dentition and is frequently found in the Negro. Professor Drennan (1937) has demonstrated the presence of this same Sinanthropic *torus mandibularis* among his Bushman and Hottentot skulls from the Cape Province.

In the light of these salient parallels between an ancient Oriental type and South African types, living and extinct, Professor Drennan's report (1936) on the presence of a Pithecanthropoid femur in his collection of African skeletons, receives an added corroborative significance.

All this seems to point to the fact that Weidenreich's claim for *Sinanthropus* being the generalised type from which Mongol races sprang, is too modest, and that it can be enlarged. If the *Sinanthropus* diagnosis of the Lake Eyassi skull is correct, and there is no reason for doubting it, then the ancient oriental generalised features of femur, jaw, and incisor teeth found in our living African types, may not be parallels, but may point to the African indigenous races having an origin from a Sinanthropoid type represented by the Lake Eyassi skull, and having evolved through some such stages as I have indicated. If this is so, then it becomes a possibility that the Sinanthropic type is the ancestral type of all mankind.

In the light of all this evidence from the skeletons and the endocranial casts, a tentative genealogical tree for African races may be drawn up.

All mankind is derived from the Sinanthropic type. In Africa this stem gave the closely related types of Rhodesian Man and Florisbad Man. From some such stock as the Florisbad type arose two divergent stems, the gerontomorphic Australian and the pedomorphic types of Africa. The Bush physical type diverged very early from this pedomorphic stem and differentiated itself from the Boskop physical type. Later, hybridisation with foreign elements resulted in ever-increasing evidence of the great variety of normal variations seen in the Boskop and Bush physical types.

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THE EVOLUTION OF PSYCHIATRY

BY

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Presidential Address to Section F, delivered 8 July, 1937.

On receiving the invitation to accept office as President of this section, I was unable at first to think of any good reason why this honour should have fallen upon me. I reviewed my past fifteen years of membership, and was obliged to confess that the total number of occasions on which I had actively participated in the work of the Association could be enumerated on none of the fingers of either hand. Indeed, my only claim to office appeared to be the somewhat slender one that I had paid my annual subscription with reasonable regularity, and I could hardly believe that this was so remarkable or unusual that it merited such signal recognition. I could, therefore, only assume that, in conferring this distinction upon me, you were giving expression to your desire to honour, not myself personally, but the profession of psychiatry as a whole On this assumption, I ventured to think that it might be not inappropriate if I made use of this opportunity to say something about that branch of human activity with which I happen to be officially associated.

It is a curious fact that few people, even among the more enlightened, appear able to consider the subject of insanity with emotional tranquillity and intellectual detachment. This attitude is largely a legacy from the past, from the times when the insane were regarded with superstitious fear, and its persistence to this day is an indication of the extent to which, in a supposed age of reason, the human mind is still dominated by prejudice and passion. I have chosen "The Evolution of Psychiatry" as the subject of this address in the hope that this review of the development of mental medicine, however brief and inadequate it may be, may help to remove some of the misunderstandings concerning the mentally abnormal and their treatment.

There can be little doubt that the human race has been subject to mental disorders from the earliest times. Primitive man attributed all diseases, mental as well as physical, to the agency of supernatural forces. He believed that sickness of every kind was caused by magic or witchcraft used by some malevolent person, or that it resulted from the actions of evil spirits which entered and took possession of the patient's body. The primitive peoples of our own time still hold these beliefs, of which our South African natives provide us with frequent examples.

The treatment of disease was in the hands of medicine men or witch doctors, whose function it was to drive out or placate the evil spirits, or to counteract the magic by means of various spells, rites and counter-magic. In cases of supposed spirit possession, surgical practices were sometimes employed on the hypothesis that the supernatural lodger would leave the body if provided with a convenient means of egress. It is not unlikely that the original owners of the six Bushman skulls showing evidence of trepanation, recently described by Professor Drennan of Capetown (1), were subjected to this operative procedure as a result of this belief.

Among the ancients in historical times, madness was attributed to possession by evil spirits sent by an outraged deity as a punishment for disobedience to divine commands. This theory was universally accepted until comparatively recently, and, even in these presumably enlightened days, is still regarded, by certain religious sects, as a complete and satisfactory explanation of the causation of mental disorder.

One of the earliest recorded instances of this belief is that contained in the Old Testament concerning Saul, King of Israel (2) (c. 1013 B.C.), who, for his shortcomings, was troubled at times by an evil spirit from the Lord. Fortunately for Saul, the visits of this unwelcome guest could usually be summarily terminated by the music of David's harp. The case of Nebuchadnezzar, King of Babylon (3) (c. 570 B.C.), is another familiar example of the belief that insanity was a direct punishment inflicted by the Almighty for disobedience to His commands.

In the earlier period of ancient Greece similar notions prevailed. All diseases were attributed to the maleficent activities of one or other of the numerous gods, to whom prayers and sacrifices were offered in order that the patients might be cured.

In opposition to the generally accepted theories of that time, Hippocrates, the father of medicine (460-370 B.C.), taught that diseases arose from natural causes and could only be properly understood by close clinical observation of the facts they presented. He was the first to enunciate a rational concept of mental disease. He asserted that mental disorders were similar in nature to bodily disorders and that insanity resulted from disturbances of the brain, which he identified as the organ of mind. He distinguished three forms of insanity—melancholia, which he attributed to an excess of bile; mania or insanity with violence; and dementia or mental weakness. He also recognised practically all the etiological factors, mental and physical, now enumerated in modern treatises on psychiatry.

For three or four hundred years after the death of Hippocrates his methods of observation and clinical enquiry continued to flourish, and mental disorders received a considerable amount of attention from physicians. Cornelius Celsus (25 B.C.—A.D.

50), a physician who practised in Rome during the first century of the Christian era and compiled a record of the medicine of this period, describes in considerable detail, in his work "On the Medical Art," the rules to be followed in the treatment of insanity. Excited patients, he directs, should be intimidated or starved, fettered or flogged. Depressed patients, on the other hand, should be diverted, encouraged and cheered.

Even if the methods used at the time were in some cases rough, they were at least well-intentioned, and not entirely irrational. Generally speaking, insanity was regarded as a disease requiring medical treatment, and only those who were dangerous or violent were subjected to restraint or incarceration.

After the advent of the Christian era the treatment accorded these unfortunate people steadily deteriorated. With the fall of the Roman Empire (A.D. 410) Europe was plunged into a state of ignorance and barbarism. The influence of an all-powerful church, with its emphasis on the life to come and consequent indifference to the things of this world, contributed not a little to the intellectual stagnation which characterised the early Middle Ages. The soul and its eternal welfare were the only things that mattered; the body was dross. The bible and other sacred writings were presumed to contain everything necessary for the guidance and welfare of mankind, and any unprejudiced criticism or spirit of enquiry was branded as heresy.

Under such conditions a return to the primitive stage of superstition and mysticism was inevitable. Mental disorders again came to be ascribed to supernatural causes, and the unhappy insane were universally regarded as possessed by spirits, divine or diabolical. Sometimes, when the morbid manifestations took the form of religious fervour in harmony with prevailing religious beliefs, the individual was revered as a saint or prophet and his babblings listened to with reverence as inspirations from God. More often, however, the symptoms were so contrary to the prevailing creed that only Satan or his minions could be held responsible, and, with few exceptions, insane persons were regarded as tenanted by devils.

In the 16th century Luther (1483-1546) and Calvin (1509-1546) believed insanity to be caused by Satan. Two hundred years later John Wesley (1703-1791) declared that "to give up witchcraft is to give up the Bible," and expressed the conviction that "most lunatics are really demoniacs."

From this belief in demoniac possession arose the barbarous practice of witch-burning, a form of pious exercise which maintained an unwholesome popularity for many years. It was based on the authority of Holy Writ and presumably justified by scriptural injunctions such as those contained in Exodus xxii, 18, "Thou shalt not suffer a witch to live," and in Leviticus xx, 27, "A man also or a woman that hath a familiar spirit or that is a wizard shall surely be put to death." During the 15th and 16th

centuries, the vaunted age of reformation in religion, medicine and philosophy, Protestants and Catholics, in the name of a loving and merciful God, vied with each other in sending hapless women to the stake. In England alone, during the first 80 years of the 17th century, 40,000 of these poor demented creatures were condemned as witches, tortured and burnt.

The physicians of those days paid little attention to the medical aspects of mental disorder. Inevitably their attitude to insanity and its treatment was coloured by the superstition and demonism of the times and in keeping with the spirit of an age indifferent to human suffering.

During the 17th century the belief in the demoniac possession of the insane gradually subsided without, however, effecting any concomitant amelioration of their lot. Although there was a cessation of the active religious persecution of which they had been the victims, nothing was done for their welfare; they were merely removed to madhouses or prisons to prevent them from troubling their fellows. The community, having thus eliminated them, regarded its duty as done In the 18th and well into the 19th century, conditions in the grossly overcrowded "madhouses" of Europe remained truly deplorable. The insane were confined in dark cells, chained, cowed by whips and other instruments of punishment, and were more neglected and worse treated than wild beasts.

As an example of the conditions then prevailing, the following brief excerpt may be quoted from the Report of the Committee on Madhouses appointed in England in 1815.

Regarding the Bethlem Asylum the report states:—

> "In the men's wing six patients in the side-room were chained close to the wall, five were handcuffed, and one was locked to the wall by the right arm as well as by the right leg. Except the blanket-gown these men had no clothing; the room had the appearance of a dog-kennel. Chains were universally substituted for the strait-waistcoat. Those who were not cleanly, and all who were disinclined to get up, were allowed to lie in bed; in what state may be imagined. One man had a stout iron ring riveted round his neck, from which a stout chain passed to a ring made to slide upwards or downwards on an upright massive bar, more than six feet high, inserted into the wall. Round his body a strong iron bar about two inches wide was riveted; on each side of the bar was a circular projection which, being fastened to and enclosing each of his arms, pinioned them close to his sides. The effect of this apparatus was, that the patient could indeed raise himself up so as to stand against the wall, but could not stir one foot from it, could not walk one step, and could not even lie down except on his back; and in this thraldom he had lived for twelve years. During much of that time he is reported to have been rational in his conver-

sation. It is painful to have to add that this long-continued cruelty had the recorded approbation of the committee of management, the medical officers, and of all the authorities of the hospital."

The report further states that the overcrowding was terrible, the stench intolerable; that there were no arrangements for heating, and many of the unfortunate inmates were almost naked.

Some of the barbarous practices to which the insane were subjected were introduced during the 18th century by physicians, themselves humane men, who reasoned that, as the mind was disorganised and deranged, it could be shaken up and rearranged by means of powerful stimuli, physical and mental.

With this end in view, some of them displayed amazing ingenuity in devising methods of inducing physical discomfort or causing acute mental perturbation by arousing fear or other powerful emotion. Various forms of water cure were invented, such as shutting the patient in a pitch-dark closet and precipitating upon him, suddenly and unexpectedly, douches of ice-cold water, or immersing him under water in a bath and keeping him there until he was on the verge of asphyxiation. Another form of treatment, highly esteemed at the time, consisted of spinning the patient at a high speed. A number of monstrous instruments, in the form of revolving chairs, swinging beds and hollow wheels, were used, by means of which the unfortunate patient was centrifuged until he became quiet and promised to behave, or, as more commonly happened, until he vomited. Needless to say, these well-meant but horrible varieties of treatment soon deteriorated into mere methods of punishment for patients who were disobedient, troublesome or violent.

It is only just, however, to point out that these practices were not inspired, as so much of the treatment of the insane has been, by wanton cruelty and a disregard for all humane principles. Indeed, Johann Christian Reil (1759-1813), a German psychiatrist of the period and one of the foremost advocates of their use, strongly condemned the conditions under which the insane were housed in most of the asylums of his day. "These unfortunate creatures," he says, "like criminals, are thrown into low dens which the eye of humanity never pierces. . . . Whips, chains and dungeons are the only means of persuasion employed by their masters, who are as barbarous as they are ignorant." (4.)

The employment of such misguided forms of treatment is to be accounted for by the fact that, of the physicians who devoted themselves to the care of the mentally disordered at the end of the 18th century, even the few enlightened ones were unable completely to free themselves from the contempt and prejudice with which the insane were generally regarded. Their conception of mental disease was dominated by religious and philosophical theories, and the treatment of mental patients was con-

ducted on the assumption that mental disorder was caused by sin or the passions, and was the end-result of a course of conduct which the patient had chosen of his own free will. It is easy to see how such views gave rise to therapeutic measures which in their nature were mainly harsh and punitive, though not, in their application, intentionally cruel.

In spite of the barbarity of their methods of treatment these men were at least inspired by a genuine desire to study and, if possible, to cure their patients. This of itself was a great advance at a time when the insane were almost universally neglected, despised and aimlessly tortured; and it was the forerunner of the humanitarian movement which followed and which eventually led to conditions under which mental patients came to be looked upon, not as wild beasts or worse, but as sick human beings in sore need of the commiseration and kindly care of their more fortunate fellows.

The first experiment in the humane treatment of the insane was undertaken at the Retreat, York, an asylum founded in 1792 by William Tuke, a citizen of York and a member of the Society of Friends. Shortly afterwards, on 24th May, 1798, Philippe Pinel, physician to the Paris Bicêtre, removed the fetters from 49 of the insane who were there incarcerated. About the same time Vincenzo Chiarugi, in charge of the St. Boniface Asylum at Florence, introduced new methods of treatment and abandoned the use of chains and manacles.

The reforms, of which these men were the pioneers, were not immediately accepted. Like most reformers, they had to contend against the mental inertia and deeply-rooted prejudices of their day, and half a century was destined to elapse before the abuses against which they fought were finally and universally eradicated.

The initiation of this humanitarian movement, 140 years ago, may be regarded as the beginning of modern psychiatry. From that time the conditions under which the insane were treated began to improve and the foundations were laid for the later scientific study of mental disease.

The 19th century witnessed a steady advance in methods of administration and treatment in institutions for the mentally disordered. At the same time investigations into the problems of mental disease were extensively conducted on lines similar to those followed by research workers in other branches of medicine.

The work of neuropathologists, such as Nissl and Alzheimer in Germany and Mott in England, contributed much information on the pathology of the nervous system in some mental diseases, but little additional knowledge of the essential factors in their causation. A notable exception is, of course, general paralysis, which was first differentiated by Bayle as a separate form of insanity, a specific clinical entity, as long ago as 1822, and finally established as merely a variety of syphilitic infection when

Noguchi and Moore, in 1913, demonstrated the spirochaete of syphilis in the cerebral cortex of a number of general paralytics.

It cannot, however, be claimed that the remarkable scientific developments which took place in medicine and surgery during the 19th century were equalled in the difficult and special sphere of psychiatry. The methods of investigation which proved so fruitful of results in so many forms of physical disease failed to yield a corresponding harvest in the field of mental disorder. Psychiatrists found themselves still called upon to treat many patients in whom the essential nature of the malady remained obscure, and for whom the treatment was necessarily largely empirical and symptomatic. Also, because of the frequently vague and elusive nature of the symptoms, particularly in the early stages of disorder, diagnosis was often uncertain and difficult. Under such conditions it is not surprising that psychiatrists tended to become resigned to the limitations of scientific knowledge on the problems of the mind, and to manifest this spirit of resignation by devoting themselves to the practical care of the mentally disordered rather than to the scentific investigation of mental disease. This attitude of psychiatrists during the latter part of the 19th century was probably accentuated by the attitude of the public and the medical profession in general towards mental disorder and mental hospitals. The tendency remained, as indeed it does to this day, to look upon mental disease as a subject to be treated either with unseemly levity or as something sinister and shameful, to be spoken of only with bated breath, but, in any case, as a condition, in its nature and origin, essentially different from bodily disease and therefore beyond the sphere of ordinary medicine. As a consequence of these views the practice of psychiatry was carried on, until comparatively recently, somewhat apart from the main body of medicine, while the domain of the specialist in mental diseases was regarded as co-terminous with the boundary walls of the asylum.

With the beginning of the present century, however, psychiatric interests began to be centred less on problems of institutional care and administration and more on the wider social and medical problems related to mental disease. Since then psychiatry has gradually abandoned its former more or less exclusive pre-occupation with the later manifestations of the more serious types of mental disorder, and has been directing a greater amount of attention to mental ill-health in its earlier stages and less malignant forms. During the past thirty or forty years the general trend of psychiatric activities has been in the direction of prevention and early treatment with the object of keeping people mentally well and socially efficient, and of restoring as quickly as possible to health and social usefulness those who become mentally disabled. This is the underlying aim which has found expression in the wide extension of psychiatric activities of recent years. Formerly confined almost entirely within the narrow limits of institutional practice, psychiatry is

now actively engaged in the investigation and treatment of all forms of mental deviations and maladjustments. This development has been accompanied by an awakening of public interest in mental hygiene, a movement which was first begun by Clifford W. Beers in Connecticut in 1908, and has since extended to every civilised country on the face of the globe.

Fifty years ago, psychiatrists were largely governed, in their attitude to mental disease, by the material concepts of general medicine. It was believed that pathological, bacteriological and chemical research, which had achieved such brilliant results in the sphere of physical disorders, would eventually be equally successful in elucidating some of the commoner problems of mental disorders.

This belief, which is still rightly held, has of late years fallen somewhat into the background, the physiogenic concept has become subordinated to the psychogenic concept, and emphasis has been directed rather to the mental and emotional factors in the causation of mental disturbances This new direction of psychiatric thought has unquestionably been mainly due to the influence of Sigmund Freud of Vienna, whose dynamic concept of the mind as an interaction of psychological forces has shed much light on the nature of mental processes, both normal and abnormal. Apart from the merits or otherwise of the Freudian doctrine of psychoanalysis as a whole, there is no question that psychoanalytic researches have contributed greatly to our knowledge of the pathology of the mind and of the mental mechanisms by which symptoms are produced.

Another leader of psychiatric thought, whose influence has been almost as great as that of Freud, is Adolf Meyer of Baltimore, the originator of the psychobiological concept of mental disorder. According to this theory the individual is regarded as a biological whole, as a psycho-somatic unit, and mental disorder as a morbid state resulting from unhealthy habits and reactions on the part of the human organism, rather than as a disorder of any special organ or system. In its practical application psychobiology is not restricted by any particular theory or dogma, but seeks to discover all the factors, physical, mental and environmental, which may account for the mental disorder and which, when discovered, will indicate the most promising lines of treatment.

The methods of psychobiology are specially useful in the investigation and treatment of those less well-defined mental disturbances associated with anti-social conduct. Of recent years psychiatric researches in the problems of crime and especially of juvenile delinquency, have contributed much towards the better understanding of these forms of social maladjustment. This is reflected in the more enlightened attitude of the courts and the public towards the misdemeanours of youth, and in the substitution of treatment and guidance in place of former methods of repression and punishment. The transfer this year of juvenile

reformatories from the Department of Prisons to the Union Department of Education is eloquent testimony of the extent to which psychiatric views on juvenile delinquency are being accepted in the Union. It is to be hoped that the assumption of this important responsibility by an education department will not be followed by a neglect of the psychiatric aspects of the problem. While it may be true that the majority of juveniles who qualify for entry into a reformatory are in need chiefly of suitable environmental and educational influences, it is nevertheless fairly certain that some of them will require something more. This something more is that special kind of investigation and treatment which it is the function of psychiatry to provide.

The place of the psychiatrist in the special field of mental defect is one about which there was no dispute until recently. For many years the care and treatment of the feeble-minded were left almost entirely in his hands. The interest shown by the psychologist and the educationist in this particular problem was, to say the least, meagre, until their attentian was attracted by the introduction, in 1908, of the Binet-Simon scale of tests for measuring the intelligence of school children. Goddard, the American psychologist, who was one of the first to realise the value and to make extensive use of the new tests, did much to popularise them, and psychologists everywhere developed an almost feverish industry in devising modifications of the original scales and in applying them to all and sundry.

One of the major results of these activities was the discovery of the high-grade feeble-minded person—the moron. The tests revealed what had previously been overlooked, that many persons regarded as normal were in reality suffering from slight degrees of intellectual defect, and, further, that this defect was frequently associated with social failure of one kind or another.

Unfortunately, the somewhat over-exuberant enthusiasm which attended the introduction of this new weapon in the armoury of psychological science led to a certain loss of perspective. The new method appeared to bring psychology into line with other more exact sciences by reducing the mind to measurement, and the inherent limitations of the tests were overlooked. For a time it was generally and erroneously assumed that the presence or absence of mental defect could be decided on the results of examination by these tests alone, and many persons, who would not now be regarded as such, were perfunctorily classed as feeble-minded. At this period, when the hunt for the moron was in full cry, the belief arose that such problems as pauperism, vagrancy. delinquency, crime, prostitution, and so on were chiefly problems of mental defect—to be satisfactorily explained and finally expressed in terms of levels of intelligence. It was forgotten that these scales measure—somewhat arbitrarily—only one aspect of the mind, and that ability to carry on successfully in the world depends not only on intelligence, but also on other

essential mental qualities such as temperament, character and practical wisdom or common sense.

With the rectification of these early mistakes, the application of intelligence tests has come to be regarded as a useful and important aid in the diagnosis of mental deficiency, but not as the only and infallible criterion.

The contribution made by psychologists during the past thirty years to the better understanding of the feeble-minded has been of considerable value to psychiatry. The problems of mental defect are not. however, only psychological, and they cannot be properly understood and handled if the medical, biological and social aspects are neglected. These aspects are unquestionably psychiatric problems. Yet there seems to be a regrettable and growing tendency on the part of the psychologist and the educationist to claim the whole domain of mental defect as theirs, and to deny the psychiatrist the privilege of remaining within a province peculiarly his own before the moron attained his present popularity. It is surely a little unreasonable that the psychiatrist should be expected to abandon to others a field of activity with which he is historically associated and in which he has, to-day no less than formerly, highly important functions to perform. The truth is that the psychiatrist, the psychologist and the educationist have each their place in this branch of human endeavour, and it will be unfortunate if petty professional jealousies are allowed to interfere with the carrying on of the work in a spirit of harmonious co-operation and mutual respect.

One of the more important developments of modern psychiatry, with its emphasis on prevention and early treatment, has been the greater attention given to the physchiatry of childhood.

In accordance with modern psychopathological concepts, many of the mental disabilities of the adult are now believed to originate from faulty mental attitudes and reactions developed during the early years of life. This belief has led to the more intensive study of the morbid mental manifestations often seen in children and to the development of the movement known as child guidance. The essential aim of this movement is to assist the child to solve his difficulties, to meet his problems, in a sane and satisfactory way, so that he may be spared not only unnecessary suffering in his youth, but also mental incapacity and social failure in later life.

Of the various mental disturbances which may occur in children the majority are simple to elucidate and easy to treat, when they are dealt with promptly, before the unhealthy mental habits and reactions have had time to become fixed. Psychiatry is, of course, concerned with these minor maladjustments of childhood as well as with the less common but more serious conditions such as pronounced behaviour disorder and definite nervous or mental disease. In other countries, child guidance

is therefore almost universally carried on under the control of psychiatrists with special training and experience in the work. In South Africa, however, there is a tendency for the psychologist to encroach on this province, and to undertake in children the treatment of morbid conditions outside the scope of ordinary psychological practice. There is a similar unfortunate tendency for lay psychologists to treat, by means of one or other of the methods of mental analysis and psychotherapy, adult patients suffering from mental abnormalities. It is argued that, as the treatment in so many of these cases is mainly psychological, the psychologist is competent to give it and the psychiatrist is unnecessary, unless the psychologist decides that the patient requires medical or psychiatric treatment. It is not clear in what way the psychologist will be able to make such a decision, since he is presumably unacquainted, except possibly theoretically, with the pathological conditions, mental and physical, he is supposed to be able to recognise. In any case, it is open to serious doubt whether the treatment of morbid mental states, involving enquiries into the patient's most intimate and delicate personal affairs, can safely be practised except by those with a medical training and subject to a strict professional discipline in their relations with their patients.

Of all the developments of psychiatry in recent years perhaps the most significant is the change which is taking place in its relationship with general medicine This change is being brought about by an altered outlook on the part of both. On the one hand, psychiatrists, after a temporary swing in the direction of over-emphasis of the psychogenic concept of metal disorders, are returning again to an appreciation of the fact that psychiatry, no less than other branches of medicine, must be founded on the basic medical sciences of anatomy, physiology and pathology. On the other hand, the medical profession in general is beginning to focus attention on the patient, rather than on his disease, to treat the sick person as an individual human being rather than, as Bernard Hart puts it, "an uninteresting vehicle containing some fascinating pathological process."

This re-awakening of interest in the patient implies a fresh realisation of the importance of the mental aspects of illness. The successful practitioner has always, of course, treated his patient's mental condition as well as his bodily disease, even though he may have done so unintentionally and unconsciously. Not so long ago the conscious practice of any psychotherapeutic treatment by a medical man was generally regarded as savouring of quackery. The Great War effected a radical change in this attitude by the lessons which it taught of the importance of mental factors in disease. In the course of this conflict it was found that men on active service were liable to become incapacitated by a condition at first termed "shell-shock," but later recognised as a psychoneurotic manifestation, a form of minor mental breakdown resulting from the stress and strain of warfare.

The large numbers of these cases of psychoneuroses among the troops, cases of genuine disability for which there was no adequate physical explanation, forced attention to be given to the mental factors in the causation of war disablement and, indirectly, brought about a new realisation of the importance of similar factors in many of the disabilities occurring in times of peace.

The very large part played by the mind in the production of ill-health and incapacity is not, however, as yet by any means generally recognised by the medical profession. The outlook of the average practitioner of medicine is still largely governed by a concept of disease founded on a material pathology. His training as a student is devoted almost exclusively to the consideration of the bodily aspects of illness; he is taught to look always for the organic conditions underlying the patient's symptoms; and he is apt, when he later enters practice, to fall into the error of concluding that illness for which no physical basis can be found is no illness at all, but simply malingering. This medical bias towards the physical side of disease has been largely responsible for the failure to recognise, until recently, the prevalence of the psychoneuroses as a cause of disability. As an indication of the frequency with which they occur one or two recent publications may be quoted:

In 1934 Sir Maurice Cassidy stated that 39 per cent. of the cardiac cases coming under his observation were entirely psychoneurotic in origin. (5.) In 1935 Dr. J. L. Halliday, Regional Medical Officer for Glasgow area under the National Insurance Act, found that, of 1,000 consecutive cases of panel patients absent for more than twelve weeks, one-third proved on investigation to be disabled primarily by psychoneurosis, although only 2 per cent., according to the medical certificates, had been diagnosed as such. (6.) And in 1936 Dr. Thomas M. Ling, medical officer to Joseph Lucas, Ltd., Birmingham, reported that, in 200 consecutive cases of sick employees, the condition was essentially psychoneurotic in 27 per cent. (7.)

It has been estimated that in Great Britain there are about three million people suffering from psychoneuroses for which they are in need of treatment. The only treatment likely to benefit the psychoneurotic—treatment by psychotherapy—is seldom provided, partly because of the prejudice against its use, but principally because the condition is often mistaken for something else. The psychoneuroses lack the urgent and attention-compelling features of surgical emergencies and devastating epidemics, and their neglect is not followed by any dramatic consequences. They are not killing diseases; they do not, except rarely, cause total incapacity; but they reduce efficiency, destroy their victims' peace of mind and, because they are so common and so chronic, add enormously to the sum total of human misery.

There is, however, ample evidence that the importance of the mental aspects of ill-health are at last being recognised by

those concerned with medical education and by other leaders of medical thought.

In a Report on Medical Education and the Reform of Medical studies, prepared by Dr. Etienne Burnett for the Health Committee of the League of Nations in 1933 (8), it is stated that

> "the complaint is heard that the excessive division of labour and even the undeniable progress of medical science have resulted in a new form of medicine, concerned with the individual organ, which has driven out the treatment of the organism as a whole, and that the doctor has ceased to understand the psychology of the patient as a human being. The patient turns to the quack for the suggestions and illusions which the doctor can no longer give him."

And again:

> "The best means of combating quackery will be the training of the student as the complete doctor, conversant with all branches of his art, including the psychology of the patient."

In 1934 the British Medical Association Committee on Medical Education (9) stated, with reference to psychological medicine and psychotherapeutics:—

> "The importance of this aspect of diagnosis and treatment to the general practitioner can scarcely be exaggerated. . . . It is not only possible but imperative that a general knowledge of the nature of the psychoneuroses and of the lines on which they should be dealt with should be taught to the student . . . at the same time he should be taught the importance of a definite appreciation of the mental attitude of the patient in the course of every illness."

Similar opinions are expressed in the Report of the Conference on the Medical Curriculum held in England in 1935 under the chairmanship of Lord Dawson of Penn (10), and in the Report of the Commission on Medical Education in the United States, published in 1932. (11.)

These authoritative statements indicate clearly the modern tendency to regard illness not simply as a disease of organs and cells, but rather as a *dis*-ease of the individual, a loss of that ease and well-being characteristic of the healthy functioning of body and mind. This change of outlook is likely to be followed, in the course of time, by a corresponding change in medical practice, whereby due attention will come to be given to the personality of the patient and his reactions as a whole, no less than to his malady. In this desirable development, psychiatry may be expected to play a not unimportant part.

The science of medicine, founded on this wider basis and including within its scope all that pertains to human health and sickness, appears destined to exercise in the future a greater influence than ever before as one of the most important agencies in the progress of mankind.

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THE PULSATION VARIABLES:

A STATISTICAL AND ANALYTICAL STUDY OF THE PHENOMENA OF CEPHEID AND LONG PERIOD STELLAR VARIABILITY

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CHAPTER 1.—INTRODUCTION.

Of the numerous theories that have been proposed to explain the phenomena of regular stellar variability, that known as the pulsation theory has been the most successful. In this theory, first propounded in its modern form by Shapley, and subsequently developed mathematically by Eddington, the variable is assumed to be undergoing purely radial oscillations about an equilibrium configuration. This pulsation of the body of the star causes variations in the photospheric radius and temperature, and hence also corresponding variations in the light emitted, and in the radial velocity. In spite of the arguments adduced against this picture, it still appears to be the most fruitful one yet put forward, and it is the object of this paper to discuss the pulsation theory and its application to the variables of Cepheid and long period class.

The theory in its original form was applied only to the Cepheid variables, but it has long been recognised that the long period variables show so close a resemblance to the former that it is likely that they are both ultimately due to the same phenomenon. Thus Shapley (1) concludes that the pulsation theory can be extended to the long period variables "on the basis of the observed similarity with Cepheids in bolometric absolute magnitude, radiation variations, spectral peculiarities, and galactic distribution. The dissimilarities, which are only those natural to the different evolutionary stages of the two groups, affect the mean density, the average spectrum, the visual absolute magnitude, and the mean distance for a given apparent magnitude."

The best-known summary of the objections raised against the pulsation theory in its application to the Cepheids is due to Jeans (2), and may best be given in his own words. According to Jeans the following conclusions follow from the application of the pulsation theory:—

"I. The luminosity of the star would be in phase with $\underline{r}$, instead of with $\dot{\underline{r}}$ $(= dr/dt)$ as observed.

II. The light curve would show fore-and-aft symmetry, contrary to observation, and it is difficult to suppose that the inclusion of terms of second and higher orders in the displacement could modify this.

III. The pulsation would disappear altogether in a period of about 100,000 years, and this is too small to reconcile with the observed frequency of Cepheids in the sky.

IV. We should expect to find oscillations of all possible amplitudes down to zero, whereas no Cepheids are known whose amplitudes of oscillation are less than a certain limiting value.

V. We should expect to find oscillations of different and incommensurable frequencies in progress simultaneously in the same star, whereas the observed light curves of Cepheids show a single definite period."

In taking these points in order, we proceed to point out that:—

I. In the discussion of a later chapter we shall show that Jeans' objection depends on a faulty interpretation of the observations. The observed radial velocities do not reflect the motion of the pulsating star, for which the luminosity is in phase with the radius, but of the atmospheric layers, in which the pulsation does not proceed as in the body of the star. The observations given later show that when the radius of the photosphere is taken into account, the phase relation predicted by the pulsation theory is fully satisfied in the Cepheids.

II. Little can be said in this connection, as it appears that the inclusion of a single harmonic of commensurable period will produce such a fore-and-aft asymmetry.

III. No conclusions can be drawn with regard to the duration of the pulsations until the source of derivation of the energy is known. It is, for example, possible, by a suitable dependence of the rate of sub-atomic generation of energy in the interior of the pulsating star on the density and the temperature, to have oscillations occurring in which the amplitude actually increases instead of decreasing. At the present stage of the theory of sub-atomic generation of energy, therefore, this argument can neither be answered nor upheld. A further point in this connection is that Jeans' argument is based on the long time scale for the life of the stars, whereas modern work tends to show that the long time scale grossly exaggerates the length of time available for stellar evolution.

IV. The statement of fact made here is definitely incorrect. The application of the photo-electric cell to stellar magnitude determinations has proved the existence of a number of Cepheids whose amplitude of variation is only of the order of a few

hundredths of a magnitude. Since it is obvious that the probability of discovery of a variable is a function of the amplitude of variation, such that smaller amplitudes are liable to a smaller probability of discovery, it therefore follows that this objection is fallacious. In fact, it recoils on the head of its proponent, since on the basis of Jeans' fission theory of stellar variability, the oscillations do not die down, so that on this theory the small amplitudes cannot be explained.

V. In this connection we note that until the ratio of the periods of the fundamental and the first harmonic has definitely been shown to be incommensurable, as was not the case when Jeans' paper was written, this argument must be considered as based on an insufficiency of information. A further point is that, as Eddington has pointed out, the harmonics may well be very much more heavily damped than the fundamental, so that after a relatively short while they will in any case not be observed in the light curve.

2. The method followed in this paper, which contains a summary of portion of a dissertation presented for the degree of Doctor of Science in the University of the Witwatersrand, a copy of which is available in the Library of the University, is to derive a picture, from the mathematical standpoint, of a radially pulsating star, and then to compare the requirements of the theory with observations. The main lines of the investigation may be summarised as follows:—

Chapter 2.—An elementary discussion of the problem is given, it being shown that in a pulsating star there is a relation between period and mean density such that for all stars built up on the same polytropic model, the period is inversely proportional to the square root of the mean density. The fundamental equations of motion and continuity are given, and the equation of energy is derived.

Chapter 3.—The "variational" equations of the problem are derived, on the assumption of small oscillations and the adiabatic approximation, and the Eddington pulsation equation then derived, and its solution discussed in the various cases of importance that arise.

Chapter 4.—The oscillations of the atmosphere of a pulsating star are discussed, and it is shown that the radial velocity of the atmosphere will differ in phase from that of the photosphere, in such a way as to satisfy the observations. The variations in ionisation and dissociation in such a star are then discussed, in connection with the observed variations in spectral type.

Chapter 5.—A brief description of certain fundamental phenomena in connection with the Cepheid and long period variables is given, with particular reference to variations in light, radial velocity, temperature, and spectral type.

Chapter 6.—Certain statistical relations in the Cepheids are discussed.

Chapter 7.—It is shown, on the basis of certain observations made in different regions of the spectrum, that the observed light variations are consistent with the joint assumptions:

(i) the photospheric radius is appreciably greater at minimum than at maximum light, and

(ii) the radiation from the Cepheids approximates very closely to that from a black body, over the range of wavelength covered by the observations.

Chapter 8.—The variations of photospheric radius and temperature are determined at various phases for several variables, the observations leading to results in complete accordance with the demands of the pulsation theory.

Chapter 9.—The relations between period, luminosity, and spectrum are considered, and interpreted in the light of the pulsation theory.

Chapter 10.—Certain statistical relations stated to exist between period, amplitude, and spectral type in the long period variables are discussed by the methods of partial correlations.

Chapter 11.—A theory of the origin of the emission lines in long period variables is shortly discussed, and the theory applied to determine the true space velocity of such a star.

Chapter 12.—This contains a table of references. The literature is extremely extensive, and only the most important papers are here mentioned. The dissertation contains a full bibliography, which could not be reproduced here.

Chapter 2.—Elementary Theory.

3. In a paper submitted to the Association some years ago (3) I showed, on the basis of the method of dimensions, that the pulsations of a gaseous star must satisfy the so-called period-density relation, namely, that for stars built up on the same polytropic model, the square of the period should be proportional to the reciprocal of the mean density. This property is possessed by all of the models proposed to explain Cepheid variation, the difference between one theory and another lying in the value of the constant predicted for the proportionality. Thus Sir W. Thomson, in a well-known investigation, discussed the oscillations of a sphere of incompressible liquid by the method of spherical harmonics, his result being that the period of oscillation corresponding to a spherical harmonic of order n is given by

$$T = 2\pi \left\{ \frac{a}{g} \cdot \frac{2n+1}{2n(n-1)} \right\}^{\frac{1}{2}}$$

where a is the radius of the sphere, and g the acceleration due to gravity at the stellar surface. This is clearly equivalent to a period-density relation of the above form.

This result is, however, of little more than historical interest. The analysis has been extended for the same type of oscillation for a gaseous sphere by Emden and by Rosseland. Emden's treatment is based on certain simplifying assumptions: (i) the surface deformation is that of a surface harmonic, the material lying between the original and the disturbed surface being of such low density that the gravitational potential due to this material may be neglected in comparison with that of the whole star; (ii) the small deformation of a spherical shell does not alter its attraction, so that the attraction of such a shell may be regarded as acting towards its centre.

With these assumptions, the equations of the problem are considerably simplified, and Emden found the period of the harmonic of order $\underline{n}$ to be given by

$$T = 2\pi \left\{ \frac{a}{g} \cdot \frac{1}{n} \right\}^{\frac{1}{2}}$$

The first of the modern treatments may be considered to be due to Ritter, who discussed the radial oscillations under adiabatic conditions of a homogeneous sphere, finding the period for harmonic oscillations of such a sphere to be given by

$$T = \left\{ \frac{3\pi}{G\,\rho\,(3\gamma-4)} \right\}^{\frac{1}{2}}$$

which is again the period-density relation. The period is here seen to depend on the effective ratio of the specific heats of the material, i.e. on the polytropic index. It is further noteworthy that the period becomes infinite for a ratio of the specific heats equal to 4/3, which is the ratio for radiation. The greater the influence of radiation, therefore, becomes, the longer becomes the period in comparison with the elementary period-density formula. These properties are shared by the more exact models proposed and dealt with by later investigators.

4. In discussing the motion of the material of a star, we have the ordinary hydrodynamical equations of continuity and motion,

$$\frac{d\rho}{dt} + \rho \cdot \operatorname{div} v = 0$$

$$\frac{du}{dt} = X - \frac{1}{\rho} \cdot \frac{\partial p}{\partial x}$$

which for radial pulsations can be be written

$$\frac{1}{\rho}\frac{d\rho}{dt} + \frac{d\dot{r}}{dr} + 2\,\frac{\dot{r}}{r} = 0$$

$$\frac{du}{dt} = -\frac{G\,M_r}{r^2} - \frac{1}{\rho} \cdot \frac{\partial p}{\partial r}.$$

In addition to these two equations, we require also an equation for the rate of change of the energy. Such equations have been

derived by Rosseland, Jeans, Vogt, Milne, Thomas, and others, often with very divergent results. The present derivation leads to results agreeing with those of Vogt and of Thomas, who have shown the other treatments to be at fault.

Let E be the energy of radiation at any point, per unit volume, ρK the thermal energy of the fluid per unit volume, ρ being the density. Let the rate of generation of sub-atomic energy per gram be 4πE, p_g the hydrostatic fluid pressure, p_r ($= \frac{1}{3}$ E) the (hydrostatic) pressure of radiation. Let the flux of radiation have components F_x, F_y, F_z per unit surface.

Consider a rectangular parallelopiped of sides dx, dy, dz, centred at (x, y, z). Let the velocity at (x, y, z) have components u, v, w. The energy contained in this element is

$$[\mathrm{E} + \rho\,\mathrm{K} + \tfrac{1}{2}\,\rho\,(u^2 + v^2 + w^2)]\ dx\,dy\,dz$$

and its rate of change is

$$\frac{\mathrm{D}}{\mathrm{D}t}\left\{[\mathrm{E} + \rho\,\mathrm{K} + \tfrac{1}{2}\,\rho\,(u^2 + v^2 + w^2)]\ dx\,dy\,dz\right\} \quad . \quad . \qquad (4.1)$$

This rate of change is made up of a number of parts:—

(i) the rate of liberation of subatomic energy

$$4\,\pi\,\varepsilon\,\rho\cdot dx\,dy\,dz$$

(ii) the rate at which work is being done by the pressure at the boundaries,

$$-\left\{\frac{\delta}{\delta x}\,(p_g+p_r)\,u+\frac{\delta}{\delta y}\,(p_g+p_r)\,v+\frac{\delta}{\delta z}\,(p_g+p_r)\,w\right\}dx\,dy\,dz$$

(iii) the rate at which the external forces $\frac{\delta \mathrm{V}}{\delta x}$ etc., per unit mass, do work,

$$\rho\cdot\left\{u\cdot\frac{\delta \mathrm{V}}{\delta x}+v\cdot\frac{\delta \mathrm{V}}{\delta y}+w\cdot\frac{\delta \mathrm{V}}{\delta z}\right\}dx\,dy\,dz$$

(iv) the rate at which energy is being changed due to the flux of radiation,

$$-\left\{\frac{\delta \mathrm{F_x}}{\delta x}+\frac{\delta \mathrm{F_y}}{\delta y}+\frac{\delta \mathrm{F_z}}{\delta z}\right\}dx\,dy\,dz$$

On equating the sum of these four terms to (4.1), and reducing the resulting equation by means of the equations of continuity and motion already given, we arrive at the equation finally in the form

$$\frac{\mathrm{DE}}{\mathrm{D}t}+\rho\cdot\frac{\mathrm{DK}}{\mathrm{D}t}-\frac{p_g+p_r+\mathrm{E}}{\rho}\cdot\frac{\mathrm{D}\rho}{\mathrm{D}t}=4\,\pi\,\varepsilon\,\rho-\sum\frac{\delta \mathrm{F_x}}{\delta x}\quad . \quad . \qquad (4.2)$$

There remain finally certain equations connecting the various physical variables. For the stellar interior we have the standard equation of transfer for the radiation,

$$\mathrm{H} = -\,\frac{\mathrm{C}}{3\,k\,\rho}\cdot\frac{\delta \mathrm{E}}{\delta\,r} \qquad . \quad . \qquad (4.3)$$

where H is the radial flux component, and k the mass absorption coefficient. If C_v is the specific heat at constant volume, R the gas constant, μ the molecular weight of the material, and γ the effective ratio of the specific heats at constant volume and at constant pressure, then we have the well-known relations

$$E = a T^4 \quad , \quad p_r = \tfrac{1}{3} a T^4$$

$$K = C_V \cdot T = \frac{R}{\mu(\gamma-1)} T \tag{4.4}$$

$$p_g = \frac{R}{\mu} \rho T$$

Finally, we shall write $df/dr = df/dr_0 \cdot dr_0/dr$, . . (4.5)
where r_0, p_0, etc., refer to the equilibrium configuration, r being the distance from the centre of the star, and the letters without suffixes referring to the disturbed state. For simplicity of writing we shall denote differentiation with respect to the time by a dot, thus $dp/dt = \dot{p}$, and with respect to the original radius by a dash, thus $dp/dr_0 = p'$.

Chapter 3.—The Variational Equations.

5. The first simplification of the problem is that introduced by Eddington, in the assumption that the opacity of the material is so high that the radiation contained in a given volume element does not leak through the material, i.e. that the motion is adiabatic. If in addition we neglect the rate of generation of subatomic energy, the equation of energy (4.2) can be written

$$\frac{dE}{dt} - (p+E)\frac{1}{\rho} \cdot \frac{d\rho}{dt} + \rho \cdot \frac{dK}{dt} = 0$$

since the flux vanishes, and the flux equation (4.3) becomes nugatory.

The second assumption is that the oscillations are small, so that we can write

$$r = r_0 (1 + r_1)$$

$$p = p_0 (1 + p_1), \text{ etc.,} \tag{5.1}$$

where r_1, p_1, etc., are small, so that terms of second and higher order can be neglected. On substituting for r, p, etc., in the fundamental equations, these are reduced to linear form, the resulting equations being the "variational equations" of the problem. We shall form the variational equations in the case first when the pressure of radiation can be neglected, so that the energy equation can be written

$$-\frac{p}{\rho} \cdot \frac{d\rho}{dt} + \rho \cdot \frac{dK}{dt} = 0$$

p being here the gas pressure.

On substituting for p, ρ, the values from (5.1), and taking into account the gas law

$$p = \frac{R}{\mu} \rho T$$

the energy equation finally reduces to the form

$$-\gamma\dot{\rho}_1 + \dot{p}_1 = 0$$

which on integration gives

$$p_1\rho_1^{\ -\gamma} = \text{constant} \qquad . \quad . \quad (5.2)$$

which is the adiabatic equation.

The equation of continuity

$$\dot{\rho} + \rho\frac{dr}{dr} + 2\rho \cdot \frac{r}{r} = 0$$

can be written

$$\frac{\dot{\rho}}{\rho} + 2\frac{\dot{r}}{r} + \frac{dr}{dr_0} \cdot \frac{dr_0}{dr} = 0$$

which on integration gives

$$pr^2r^1 = \text{constant}. \qquad . \quad . \quad (5.3)$$

On substituting from (5.1) this becomes

$$pr^2r^1 = p_0r^2\,(1 + p_1 + 3r_1 + r_0r_1^{\ 1})$$

$$= \text{constant with regard to time} \qquad . \quad . \quad (5.4)$$

Hence $p_1 + 3r_1 + r_0r_1^{\ 1} = \text{constant}$ . . (5.5)

Finally the equation of motion

$$\ddot{r} + \frac{1}{\rho} \cdot \frac{\partial p}{\partial r}$$

becomes

$$r_0\ddot{r}_1 + \frac{p_0^{\ 1}}{\rho_0}\,[1 + 2\,r_1 + p_1] + \frac{p_0}{\rho_0}p_1^{\ 1} + g_0(1 + g_1) = 0$$

But in the equilibrium configuration the hydrostatic equation holds,

$$\frac{dp_0}{dr_0} = -\,g_0\,\rho_0$$

and further, $g = GM/r^2 = g_0\,(1 - 2r_1)$, so that

$$g_1 = -\,2r_1$$

The equation of motion can therefore be finally reduced to

$$\ddot{r}_1 + \frac{1}{\rho_0 r_0}\,\frac{\partial}{\partial r_0}\,(p_0p_1) - \frac{4g_0}{r_0}r_1 = 0 \qquad . \quad . \quad (5.6)$$

On combining the adiabatic equation (5.2) with the equation of continuity (5.5), we obtain

$$p_1 = -\,\gamma\left[3r_1 + r_0 \cdot \frac{\partial r_1}{\partial r_0}\right] \qquad . \quad . \quad (5.7)$$

and on eliminating p_1 between (5.6) and (5.7) we obtain the final equation of the problem

$$\frac{\partial^2 r_1}{\partial t^2} = (4-3\gamma)\frac{g_0}{r_0}r_1 + \frac{\gamma}{r_0}\left[\frac{4p_0}{\rho_0} - g_0\,\rho_0\right]\frac{\partial r_1}{\partial r_0} + \frac{\gamma p_0}{\rho_0} \cdot \frac{\partial^2 r_1}{\partial r_0^{\ 2}} \qquad . \quad . \quad (5.8)$$

which is solved by the usual method. Assume a solution of the form

$$r_1 = \mathrm{R}(r_0) \cdot \mathrm{T}(t)$$

Then the equation separates into the two independent portions

$$\frac{1}{\mathrm{T}} \cdot \frac{d^2\mathrm{T}}{dt^2} = \mathrm{C}_1 + \frac{\mathrm{C}_2}{\mathrm{R}}\frac{d\mathrm{R}}{dr_0} + \frac{\mathrm{C}_3}{\mathrm{R}}\frac{d^2\mathrm{R}}{dr_0{}^2}$$
$$= -n^2$$

and the motion is therefore simple harmonic of the form

$$\mathrm{T}(t) = \mathrm{A}\sin(nt + a)$$

where the eigen-values n have to be determined from the remaining differential equation and the boundary conditions:

$$\frac{d\mathrm{R}}{dr_0} = 0 \text{ at } r_0 = 0\,;\; p_1 = 3\mathrm{R} + r_0 \cdot \frac{d\mathrm{R}}{dr_0} = 0 \text{ at the boundary.}$$

The equation is not in general integrable in finite terms, since the coefficients are functions of r_0 which themselves have to be determined by numerical integration for the stellar model under consideration. The numerical integration of this equation has been undertaken by Eddington for the case of a star of polytropic index 3, and by Miller for models of polytropic index 2 and 4. Thus for a star of polytropic index 3, Eddington (4) finds that the period π of the pulsation is given in terms of the central density ρ_c and the effective ratio of the specific heats γ, by the relation

$$\pi\sqrt{\rho_c} = 0{\cdot}290\,(3\gamma - 4)^{-\frac{1}{2}} \;(\pi \text{ in days}) \quad . \quad . \quad (5.9)$$

which is a period-density relation that is capable of numerical test. In a later chapter it will be shown that this relation is satisfied by the Cepheid variables, and in the mean by the variables of long period.

6. If the energy and pressure of radiation may not be neglected, adiabatic conditions being still assumed, it can be shown that the adiabatic condition (5.2) still holds, but that in this case γ is the effective ratio of the specific heats of the mixture of matter and radiation, and depends on the ratio of gas pressure to the total pressure, which according to Eddington's theory of the internal constitution of the stars is also a function of the mass of the star.

The energy equation (4.2), with the right-hand side neglected for adiabatic pulsations can be written

$$\frac{d\mathrm{E}}{dt} - \frac{(p_g + p_r + \mathrm{E})}{\rho} \cdot \frac{d\rho}{dt} + \rho \cdot \frac{d\mathrm{K}}{dt} = 0$$

i.e.

$$d\left(\frac{\mathrm{E}}{\rho}\right) + d\mathrm{K} + (p_g + p_r)\, d\left(\frac{1}{\rho}\right) = 0$$

or putting $\mathrm{V} = 1/\rho$ as the volume per unit mass, and writing

the energy per unit volume as the sum of the atomic and radiative energies,

$$Q = aT^4 + \rho K = \frac{R}{\mu(\Gamma - 1)}\rho T + aT^4$$

where Γ is the specific heat ratio for the material, this becomes

$$d\,(QV) + (p_g + p_r)\,dV = 0$$

Introducing the ratio of the gas pressure to the total pressure, β, so that

$$P_0 = \frac{R}{\mu}\rho_0 T_0 + \tfrac{1}{3}aT_0^4,\ \beta P_0 = \frac{R}{\mu}\rho_0 T_0,\ \tfrac{1}{3}aT_0^4 = (1 - \beta) P_0$$

we then have

$$\left\{\frac{\beta}{\Gamma - 1} + 12(1 - \beta)\right\} T_1 = \left\{\beta + 4(1 - \beta)\right\}\rho_1$$

The equation above for the total pressure can be written in the variational form

$$P_1 = \beta\rho_1 + (4 - 3\beta)\,T_1$$

Hence if we write

$$P = K\rho^\gamma \text{ i.e. } P_1 = \gamma\rho_1$$

where γ is the effective ratio of the specific heats, we have

$$\gamma = \beta + \frac{(4 - 3\beta)^2\,(\Gamma - 1)}{\beta + 12\,(\Gamma - 1)\,(1 - \beta)}$$

which can be finally reduced to Eddington's form

$$\frac{\gamma - \frac{4}{3}}{\Gamma - \frac{4}{3}} = \frac{4 - 3\beta}{1 + 12\,(\Gamma - 1)\,(1 - \beta)/\beta} \quad . \quad . \quad (6.1)$$

The previous analysis therefore still holds when radiation pressure is taken into account, the only change being that the value of γ is given by the above expression as the weighted mean of the values for the material and for the radiation contained in the star.

7. The adiabatic assumption will obviously break down near the surface, where the flux of radiation must be appreciable. A number of attempts have been made to discuss the oscillations in this non-adiabatic region, but without much success. Eddington concluded that the phase of the oscillation could not be altered in the non-adiabatic region, although more recently Schwarzschild (5) has concluded that in certain stellar models phase displacements of appreciable magnitude may occur in the outer 1 per cent. of the radius.

It appears, however, doubtful whether the more accurate investigations are justified, since the equilibrium theory of the internal constitution of the stars is still in a state of flux. Other problems, to which at present no really satisfactory answer can be given, such as the theory of the hydrogen content of the stars, also have an important bearing on the pulsation theory, and until these problems have been brought to a more satis-

factory state, it would appear that the elementary theory of stellar pulsations already given serves as a sufficiently close approximation to the behaviour of a pulsating star.

It remains for us to show the phase relation between the radius variations and the variations of temperature. The equation of continuity (5.4) can be written, in terms of the pulsation variables r_1, etc., in the form $\rho_1 + 3r_1 + r_0 r^1 =$ constant with regard to the time. If we introduce the time variation in the form

$$\rho_1 = \rho_0 \cos nt + \rho_s \sin nt, \text{ etc.},$$

then on substituting in the above equation we have constant

$$= \rho_c \cos nt + 3r_c \cos nt + r_0 r_c^1 \cos nt.$$
$$+ \rho_s \sin nt + 3r_s \sin nt + r_0 r_s^1 \sin nt.$$

The comparison of coefficients gives

$$0 = \rho_c + 3r_c + r_0 r_c^1.$$
$$0 = \rho_s + 3r_s + r_0 r_s^1.$$

But $r_1 = dr_1/dr_0$ is in phase with r_1, hence it follows that the variations in density differ in phase by half a period from the variations in radius. From the adiabatic equation, therefore, the radius and pressure also differ in phase by half a period, and hence from the gas law the radius and temperature are also opposite in phase. In a star undergoing small adiabatic pulsations, therefore, the radius is greatest when the temperature is least, and vice versa. This important conclusion will be tested by the observations in a later chapter, where it will be shown that in the Cepheids the maximum photospheric radius occurs at the time of minimum photospheric temperature, and vice versa.

With regard to the problem of the harmonics of higher order in the pulsations, little information is available. The solution of the equation (5.8) for the eigen-values for different harmonics has been undertaken by Edgar (6), who has shown that if $\alpha = 3 - 4/\gamma$, and if the periods of the fundamental and the first harmonic are π_1, π_2 respectively, then

$$\pi_1^2 \rho_c = \frac{10}{3} \cdot \frac{4\pi}{G\gamma\alpha} \text{ where } \rho_c = \text{central density},$$

$$\pi_2^2 \rho_c = \frac{1}{3} \cdot \frac{4\pi}{G\gamma\alpha} \text{ for } \alpha = 0{\cdot}1,\ \gamma = 1{\cdot}380$$

$$\frac{1}{1{\cdot}165} \cdot \frac{4\pi}{G\gamma\alpha} \text{ for } \alpha = 0{\cdot}4,\ \gamma = 1{\cdot}54$$

Hence $\pi_2/\pi_1 = 0{\cdot}32$ for $\alpha = 0{\cdot}1$

$= 0{\cdot}51$ for $\alpha = 0{\cdot}4$

It is clear, therefore, that since γ depends on β, and hence also on the mass, the ratio of the periods of the fundamental and the first harmonic will vary with the mass of the star. It is therefore possible that for certain masses the periods may

possess almost exact commensurability, while for masses less than or greater than this critical value, the periods become more and more markedly incommensurable, so that the oscillations show more and more marked variations from one period to another.

This appears to meet the situation in the Cepheid variables. The shapes of Cepheid light curves are representable by the composition of simple harmonic oscillations of periods which are simple submultiples of the fundamental period. Further, the irregularities of the light curves increase as the period increases from about 10 days, while it also increases for periods shorter than a day. These suggestions must, however, be regarded as purely tentative, since it is possible that the irregularities of the light curves of many variables may be due to entirely different causes, the harmonics in the pulsation being completely damped out in a short time.

Chapter 4.—Atmospheric Oscillations.

8. The investigation of the preceding chapter has shown that when a star pulsates radially, the phase of the pulsation is maintained unchanged up to the surface, so that the radius of the photosphere is greatest when the temperature is least, and vice versa. It does not, however, follow, as many investigators appear to have assumed implicitly, that the atmosphere above the photosphere will also oscillate in the same phase. A quantitative study of the oscillations of a pulsating star cannot be given at the present stage of our knowledge, but some idea of the behaviour may be obtained by qualitative reasoning.

The energy equation (4.2) can be written, putting the flux of energy in the chromosphere as Q, and introducing the volume per unit mass $V = 1/\rho$,

$$Q = \frac{1}{\rho} \cdot \frac{dE}{dt} + \frac{dK}{dt} + (p_g + p_r + E)\frac{dV}{dt}$$

If we now assume the time relations

$$Q = Q_1 \cos nt$$
$$T = A_1 \cos nt + A_2 \sin nt$$
$$V = B_1 \cos nt + B_2 \sin nt$$

then on substituting these in the above equations, taking the oscillations to be so small that terms of order higher than the first may be neglected, we have on comparing the coefficients of cos nt and sin nt,

$$c_1 A_2 + c_2 B_2 = Q_1$$
$$c_3 A_1 + c_4 B_1 = 0$$

where c_1, c_2, c_3, c_4 are certain constants. From the second equation we conclude that A_1, B_1 must be zero. Hence the temperature and the volume per unit mass of the atmosphere differ in phase by one-quarter of the period from the flux, which is obviously in phase with the photospheric temperature.

If the mass of the atmosphere remains constant throughout the period of light variation, the volume of the atmosphere is then proportional to the volume per unit mass, and the atmospheric volume is therefore displaced through 90° in phase as compared with the photospheric temperature and the light curve. The radial velocity of the atmosphere differs in phase by a further quarter period from the volume, so that the radial velocity as determined from the atmospheric layers will either be in the same, or in opposite, phase as compared with the variation in temperature and light from the photosphere. Observations show that in the Cepheids, as we shall show later, the phase of the radial velocities as determined from the absorption lines in the spectrum, i.e. as determined by the atmospheric layers, does differ from the light curve by half a period. In the case of the long period variables, the absorption line velocities are approximately in phase with the light curve, while the emission line velocities are displaced in phase by approximately half a period.

The amplitude of the radial velocity curves from lines at different atmospheric levels may be expected to show considerable variation, while the radiation from the atmosphere itself, with a temperature different from that of the photosphere, may be expected to introduce small complications. These points cannot at the present stage receive anything approaching satisfactory treatment.

9. Another point of considerable interest lies in the fact deduced above, that the temperatures of atmosphere and photosphere differ in phase by one-quarter of a period. The degree of ionisation and of line excitation depends on both these factors and on the pressure in the atmosphere, which obviously depends on the atmospheric density and the surface gravity. These variations in ionisation can also be subjected to elementary treatment.

From what we have shown in the previous section, the variation in atmospheric temperature is zero when the photospheric temperature is a maximum. Further, from the Gas Law, the atmospheric temperature must be in phase with the atmospheric pressure. Hence the variations in atmospheric temperature and pressure vanish at maximum and minimum photospheric temperature, and hence at maximum and minimum light.

The ionisation formula is

$$\log \frac{x^2}{1 - x^2} = - \frac{5042V_0}{T} + \frac{5}{2} \log T - \log P + \text{constant}$$

where x is the degree of ionisation, V_0 the ionisation potential, T the temperature, P the pressure, and C_1 constant for a given element. The condition that the ionisation be a maximum, i.e. that $x^2/(1 - x^2)$ be a maximum, is that

$$\frac{dT}{T}\left[\frac{C\,V_0}{T} + \frac{5}{2}\right] = \frac{dP}{P}$$

If T and P were in the same phase, then maximum ionisation would occur when dT and dP both vanish, i.e. ionisation and temperature would be in the same phase. In this case, however, T represents the *photospheric* temperature, while P is the *atmospheric* pressure, which we have shown to differ in phase by 90°. Hence in this case, maximum ionisation must occur at some phase other than maximum temperature, and hence other than maximum light. The ionisation in the atmosphere of such an oscillating star will have its maximum at different phases for different elements, and the mean ionisation will not be in phase with the light curve. Since the spectral class is determined by the general ionisation in most cases, it is therefore not to be expected that the spectral class will be in phase with the light curve, a conclusion agreeing with the results of observation.

While it does not appear worth while attempting to give any further detail in this discussion, it is worth mentioning that in the long-period variables, in which the bands of titanium oxide form the most characteristic feature of the spectrum, similar arguments can be applied to the discussion of the variation of the intensity of these bands. Previous discussions on these lines, such as those due to Christy, Swings, Richardson, Cambresier and Rosenfeld, and Russell are, however, all subject to the criticism that the phase relation between the photospheric temperature and that of the atmosphere has been neglected. The observed variations in the band intensity during the light variation in these variables appears, however, to be determined largely by the variations in photospheric temperature, and only to a smaller degree by variations in surface gravity and atmospheric pressure.

To summarise the results of this Chapter, we have shown that:

(i) The radial velocity of a pulsating star, derived from observations of the absorption lines in the spectrum, will be in phase with the light curve, or very nearly so.

(ii) The radial velocities from different layers in the stellar atmosphere should show more or less marked differences in amplitude and in phase.

(iii) The ionisation will not be in phase with the photospheric temperature, or with the atmospheric pressure. Each element will behave in accordance with its own ionisation equation; elements whose ionisation is determined mainly by temperature in the range under consideration will follow the variations in the light curve more closely with regard to phase than those elements whose ionisation is under the given circumstances more strongly influenced by pressure.

(iv) Similar remarks hold for the variations in the intensity of the bands in the variables of late class, the influence of temperature on the band intensity being more clearly marked than on the general ionisation.

Chapter 5.—Preliminary Remarks on Stellar Variability.

10. The forms of the light curves of Cepheids and long period variables has been the subject of much study. In general in the Cepheids the rise from minimum to maximum light is steeper than the fall after maximum, this steepness being very marked in the short period Cepheids. Ludendorff and Hertzsprung, among others, have shown that the form of the light curve depends on the period, but it does not appear that the correlation is very marked. In any case it does not appear that the analysis of the variations in visual or photographic magnitude is likely to lead very far, as I have previously pointed out in a paper to the Association (3). It would be of great interest and importance, however, if we could determine with accuracy the variations in photospheric temperature and radius during the light curve, since in this case we would have observations of the fundamental variables regarding which our theory has led us to certain predictions. This problem will be discussed in detail later, but in connection with the shape of the light curves of the Cepheids, the harmonic analysis of the variations in photospheric radius and temperature of the short period variable RS Boötis, for which these quantities can be well determined, may be given.

It is found that for this variable

$$r = 0{\cdot}148 + 0{\cdot}033 \cos (v - 256^\circ) + 0{\cdot}019 \cos (2v - 281^\circ) + 0{\cdot}010 \cos (3v - 288^\circ)$$

$$T = 7900^\circ + 2080^\circ \cos (v - 71^\circ) + 1130^\circ \cos (2v - 96^\circ) + 950^\circ \cos (3v - 106^\circ)$$

which show the important fact that the radius and temperature of a pulsating star may actually contain higher harmonics in addition to the fundamental period, an observational fact of considerable importance.

The visual light curves of the long period variables are in general of much larger amplitude than those of the Cepheids, but the greater part of the difference must be regarded as due to the large variation in the bolometric correction for different temperatures through which the star moves during the course of its pulsation. Observations of the radiometric magnitudes, which approach more closely to the bolometric magnitude, have shown that the long period variables possess on the whole radiometric amplitudes which are not appreciably larger than those of the Cepheids. Until, therefore, it is possible to estimate with accuracy the bolometric correction to be applied to the visual magnitudes at different phases, little can be learnt from a study of the visual variations only, since the variations in the bolometric correction completely overwhelm those in the bolometric magnitude which are of interest. Detailed study of the visual light curves of the long period variables, such as has been undertaken by Ludendorff and Thomas, can thus at present not lead to complete understanding of the underlying phenomena.

11. In addition to the variations in luminosity, the variable stars considered also show variations in radial velocity. The most important result for the Cepheids is that the curve of radial velocity variation is very nearly the mirror image of the light curve, maximum velocity of approach of the layers for which the velocity is determined occurring at, or shortly after, light maximum.

This phase relation of light and velocity curves has often been regarded as a cogent argument against the validity of the pulsation theory, but the argument of the previous chapter has shown that this is not the case, that in fact the observed phase relation is predicted by an extended form of the pulsation theory. The evidence of the radial velocities has been misinterpreted. and in a later chapter we shall consider the actual photospheric radius and temperature in their mutual phase relations.

Further evidence that the atmospheric pulsations do not follow those of the photosphere is provided by observations made at the Observatory of Michigan by Rufus and his co-workers, who have shown that the phase and amplitude of the radial velocity curve depend on the atmospheric height of the lines used (7). While more and more accurate observations are undoubtedly needed to decide the exact course of the phenomena, it appears clear from the observations already available that the motion in the atmosphere resembles a pulse starting from the lower levels, and not merely a radial pulsation of the atmosphere as a whole, in which all points on the same radius must be in the same phase. The evidence of the radial velocities, therefore, must be taken in favour of, and not against, the validity of the pulsation theory.

12. Further observations have shown that the variation in light and radial velocity is accompanied with marked variations in spectral type and effective temperature. The spectral changes indicate that the temperature of these stars is invariably higher at maximum light than at light minimum, in accordance with the pulsation theory, although, as we have shown, the spectral changes are not determined by the temperature of the photosphere alone, and are not necessarily in phase with the changes in the temperature.

Direct determinations of the temperature (effective) by various methods have also shown that the maximum temperature occurs very nearly at maximum light intensity, both for the Cepheids and for the long period variables. Pettit and Nicholson (8) have shown by radiometric measurements that at maximum light the photospheric radius is greater than at minimum light, in accordance with the demands of the pulsation theory.

Chapter 6.—Certain Statistical Relations in the Cepheids.

13. There are a considerable number of statistical relations connecting the various characteristics of the Cepheids, some of which appear to have a much more important bearing on the phenomena of stellar variability than others. It is important to sort out from the sometimes bewildering mass of observations and conclusions those which have a real meaning, and it appears that the only satisfactory method is to use the most homogeneous material available, and to subject it to correlation analysis. The most important, and definitely the most strongly marked correlations are those between period, luminosity, and spectral type, which will be discussed in detail in the next chapter.

In the present investigation, the material used is that compiled by the Harvard observers, mainly Robinson (9), who gives photographic light curves for 106 Cepheids, for 70 of which the median spectral type and the range in type are known from the work of Shapley and Walton. These 70 variables, the light variations in which have been determined from a large number of photographs taken with the same instruments over a large number of years, have been subjected to correlation analysis, the rough correlation coefficients being given in Table 6, I. The characteristics taken into consideration are the following: logarithm of period (x); magnitude range (y); range in spectral type (z); spectral type at maximum (a); spectral type at median light (b). In the Table we give the correlation coefficients between the variable in each column with that in each row, along with the corresponding probable error.

Since the type at median light is equal to the type at maximum plus one-half the type range, it is obvious that the correlations between type range (z) and median type (b) must be more marked than that between type range and maximum type. The correlation between x and b, therefore, appears to be due entirely to this fact, since z and a are completely incorrelated.

Table 6, I.

Rough Correlation Coefficients.

x	—	0·602 ±0·051	0·267 ±0·073	0·524 ±0·058	0·662 ±0·045
y	—	—	0·500 ±0·060	0·084 ±0·075	0·345 ±0·071
z	—	—	—	0·051 ±0·079	0·409 ±0·061
a	—	—	—	—	0·888 ±0·006

The correlation between the logarithm of the period (x) and maximum and median type are both marked, the second being the larger. These are the expressions of the period-spectrum relation.

The correlation between type range (z) and magnitude range (y) is rather large, and does not appear to have been previously observed. The explanation of this relation will be given in a later chapter, where it is shown that during the pulsation of a Cepheid, the radius and temperature are connected by the relation

$$\text{radius} \times \text{temperature} = \text{constant}.$$

Hence it is clear that the range in the bolometric magnitude is twice that in the logarithm of the temperature, which will give rise to a correlation between visual or photographic magnitude range and the range of spectral type, such as is here observed.

The relation between period and magnitude range has not yet been explained, although it has been observed on previous occasions. One possible explanation is that the effect may be due largely to the influence of selection, stars of long period and large amplitude being more likely to find their way into a discussion such as that of Robinson's than stars of long period and small amplitude.

The partial correlations for the above material have also been worked out (10), and it is found that we have significant correlations between: logarithm of period and maximum type, logarithm of period and magnitude range, logarithm of period and median type, magnitude range and type range. On the other hand, the correlations between magnitude range and median type, type range and maximum type, logarithm of period and type range, type range and median type, are found to be insignificant, in comparison with their probable errors.

The significant correlations can all be explained by the pulsation theory, at least with qualitative success.

Chapter 7.—The Cepheids and Black-body Radiation.

14. The study of the spectral energy distribution of the stars has led, in the main, to one important and striking conclusion, namely, that, except at the ends of the spectral sequence, and in the far ultraviolet, the stars radiate to a close approximation as black bodies.

Little work has been done on this problem in the Cepheids, but a recent paper by Kox (11) gives observational material from which a test can be made. The complete discussion has been given elsewhere (12), but in this place we may discuss the

evidence bearing on the black-body properties of the radiation from the Cepheids.

Consider observations made, for simplicity, in two wavelengths, λ_1, λ_2. Let the corresponding magnitudes at maximum light be m_1, m_2, the light intensities per unit photospheric surface be I_1, I_2, and the photospheric radius be r. Then

$$m_1 = -2{\cdot}5 \log I_1 - 5 \log r$$
$$m_2 = -2{\cdot}5 \log I_2 - 5 \log r.$$

If the corresponding quantities at minimum light are $m^1{}_1$, $m^1{}_2$, $I^1{}_1$, $I^1{}_2$, r^1 respectively, the amplitudes A_1, A_2 of the light variation in the two wavelengths will be given by

$$A_1 = m^1{}_1 - m_1 = -2{\cdot}5 \log (I^1{}_1/I_1) - 5 \log (r^1/r)$$
$$A_2 = -2{\cdot}5 \log (I^1{}_2/I_2) - 5 \log (r^1/r). \quad . \quad . \quad (14.1)$$

The ratio of the amplitudes of variation is therefore a function of the intensities per unit surface, but also of the ratio of the radii at maximum and minimum light. Hence from observations of the amplitude in two such wavelengths it is possible, assuming black-body radiation, to calculate the ratio of maximum and minimum radii, and also to calculate the range between maximum and minimum temperatures. If there are then similar observations in a number of wavelengths, it will be possible to correct each observed amplitude to the value it would have had if there had been no variation in the radius, and then to calculate the corresponding temperature variation in each wavelength. All these temperature ranges should, of course, be identical, so that any significant differences must be due to deviations in the stellar radiation from that of a black body.

Kox gives a table of the amplitudes in a number of different wavelengths of a normal star (Delta Cephei), to which the foregoing argument can be applied. Thus, if A_o is the observed amplitude in a given wavelength,

$$A_o = -2{\cdot}5 \log (I^1/I) - 5 \log (r^1/r).$$

Hence A_c, the corrected amplitude for no change in the radius, would be

$$A_c = -2{\cdot}5 \log (I^1/I) = A_o + 5 \log (r^1/r).$$

The quantity $5 \log r^1/r$ can be found by considering the observed amplitudes for any two wavelengths. From the data given by Kox for wavelengths $0{\cdot}415\mu$ and $0{\cdot}550\mu$, we find

$$5 \log (r^1/r) = 1{\cdot}02.$$

Each observed amplitude $A^o{}_1$ was then corrected by adding this quantity, and the temperature ranges $\triangle T$ then calculated for the corrected amplitudes A_c from Planck's formula, with the results given in Table 7, I.

TABLE 7, I.

Wavelength.		A_0		A_c		$\triangle T$
		m.		m.		°
0·405	...	1·62	..	2·64	...	1870
0·415	...	1·51	...	2·53	...	1840
0·425	...	1·41	...	2·43	...	1760
0·450	...	1·21	...	2·23	...	1770
0·475	...	1·08	...	2·10	...	1760
0·500	...	0·99	...	2·01	...	1760
0·525	...	0·94	...	1·96	...	1790
0·550	...	0·90	...	1·92	...	1820
0·575	...	0·86	...	1·88	...	1860
0·600	...	0·82	...	1·84	...	1860

The mean temperature range from the above Table is found to be 1810°, the probable error of the mean being $\pm 10°$. The probable error of an individual value of $\triangle T$ is $\pm 30°$, so that the temperature range computed by the use of the Planck formula is constant within a probable error of 30°. It is found that at wavelength 550μ, for example, an error of 0·01 magnitudes in the amplitude given by Kox for that wavelength would introduce an error of approximately 20° in the calculated temperature range. It appears extremely unlikely, particularly in view of the method used by Kox in reducing the results of various observers on various stars to a single standard system, that the results will be accurate to anything like this order of accuracy, so that the observed differences in $\triangle T$ may with safety be assumed to be due entirely to errors of observation.

A further check on this conclusion arises as follows. From Hopmann's colorimetric observations on Delta Cephei, discussed by Mochnatsch and Okunev (13), we find

$$5 \log (r^1/r) = 1{\cdot}075$$

while the temperature range is 1820°. Other temperature observations of Delta Cephei give the following results:

T.		Observer.		Method.
1620°	...	Pettit and Nicholson	...	Radiometric.
2150	...	Whipple ...	...	Spectrophotometric.
1200	...	Sampson ...	...	Spectrophotometric.

The observations justify us therefore in stating that the observed amplitudes of variation of light of different wavelengths are completely consistent with the joint assumptions:

(i) The photospheric radius varies during the pulsation in such a way that the radius is appreciably greater at

minimum than at maximum light (for Delta Cephei log (r^1/r) was found to be slightly greater than 0·2);

(ii) The radiation from the Cepheids approximates closely to black-body radiation over the spectral range covered by the investigation.

There is a further corrollary to (i); since the radius has not its mean value at maximum and minimum light, it follows that the radial velocity, determined from the absorption lines produced in the spectrum of the star by its atmosphere, does not reflect the motion of the body of the star. The observed phase lag of the radial velocities, though it still requires explanation, can no longer be regarded as a serious argument against the validity of the pulsation theory.

Chapter 8.—The Relation between Radius and Temperature.

15. The determination of the radius of a variable star at a given phase can be based on either of two mutually exclusive hypotheses:

(i) The radial velocity as determined by the displacements of lines in the spectrum determines the motion of the photosphere so that the radius of the photosphere can be obtained at any phase by integration of the radial velocity curve. This method has been suggested and used by a number of investigators. Against it there is the fundamental objection that there is no reason to believe that the atmospheric pulsations reflect unchanged those of the body of the star, as we have pointed out.

(ii) By the method of the previous chapter we can, on the assumption of black-body radiation, compute the radius and temperature at any phase by observations of the magnitude of the star made in light of two different wavelengths, such as photographic and visual or photovisual. Against this method the objection has been raised that it depends on the use of the Planck formula. The arguments of the previous chapter, however, have justified us in this assumption, and this second method is used in the present investigations.

The temperature of the star is determined by its colour index, obtained from simultaneous visual and photographic observations. The bolometric correction for this temperature is obtained from the Table given in an earlier communication to the Association (14), and the bolometric magnitude at the given phase determined from the observed visual magnitude and the bolometric correction. The radius is then determined from the bolometric magnitude and the temperature by the relation

$$\log r = -0{\cdot}20\,\mathrm{B} - 2\log \vartheta$$

where r refers to an arbitrary unit.

The material available is not very adequate to the purpose, and it is not intended to give it in detail. As an example, however, of the results obtained in this way, we give the results found for the mean light and colour curves of the cluster type variables in the cluster M3, the observations being due to Shapley (15). Successive columns give the phase in days, the photovisual magnitude, the colour index, the temperature, the quantity $-B/5$, where B is the bolometric magnitude, and finally the logarithm of the product of radius and temperature, viz.:

TABLE 8, I.

Phase	M_{pv}	C.I.	T.	$-B/5$	log $r\theta$
·000	14·97	−0·07	12,200°	−2·882	−6·969
·011	14 99	·06	12,000	−2·892	−6·971
·025	15·00	·04	11,600	−2·904	−6·969
·034	·01	−0·01	11,200	−2·916	−6·965
·045	·03	+0·01	10,800	−2·932	−6·965
068	·10	·07	10,060	−2·962	−6·964
·090	·16	·15	9,100	−3·002	−6·961
·113	·26	·22	8,450	−3·036	−6·963
·136	·38	·29	7,850	−3·070	−6·965
·158	·46	·33	7,600	−3·090	−6·971
·192	·54	·37	7,300	−3·108	−6·971
·237	·62	·41	7,000	−3·126	−6·971
·271	·65	·42	6,950	−3·130	−6·972
·328	·67	·43	6,900	−3·134	−6·973
·430	·66	·43	6,900	−3·132	−6·971
·486	·44	·33	7,600	−3·086	−6·967
·497	·29	·24	8,250	−3·046	−6·963
·520	·04	+0·02	10,700	−2·936	−6·965
·531	15·00	−0·04	11,600	−2·904	−6·969

From the complete set of observations, of which about one-third are given in the Table, we find that B/5 varies between 2·882 and 3·134, i.e. through a range of 0·252 magnitudes. Log θ is found to vary between 3·839 and 4,087, i.e. through a range of 0·249. The ranges of variation are therefore equal within one per cent. Further, it is found that maximum temperature and minimum radius coincide in phase within the accuracy of the observations, and so also do minimum temperature and maximum phase, in full agreement with the requirements of the pulsation theory.

In the last column we see further that the product of radius and temperature is very nearly constant throughout the light range, the mean value of log $r\theta$ being −6 969, and the standard

deviation of an individual value of log $r\theta$ from this mean is $\pm$ 0·0041; that is, $r\theta$ is constant throughout the entire range of light variation within a probable error of approximately 0·3 per cent. The range of individual values of log $r\theta$ is 0·013, i.e. the maximum variation in the product of radius and temperature is only one-twentieth of that in either radius or temperature alone.

This striking result is confirmed by all the other material that has been found of sufficient accuracy for the purpose, and must be regarded as of great importance in the light of the pulsation theory. The agreement in phase between photospheric radius and temperature leads to the conclusion that the radial pulsations of the body of the star are transmitted without change of phase right up to the photosphere, and that the observed phase difference of the radial velocities arises above the photosphere, in the reversing layer and the chromosphere. It is in this part of the star, then, and not in the non-adiabatic and convective zones below the photosphere that the mechanism by which the change of phase is brought about must be sought.

The interpretation of the relation $r\theta =$ constant remains to be given. It is interesting to note that the temperature θ at a point at distance r from the centre of a star, by Lane's law, is connected with r by the relation $r\theta =$ constant, if the star moves moves along a series of homologous configurations. Homer Lane's equation, however, is only valid in the interior of the star, so that we are not entitled to draw any direct conclusions from the fact that the same equation is satisfied by the photospheric radius and temperature of the Cepheids.

On the other hand, we see in the next chapter that in the Cepheids the bolometric absolute median magnitude and the logarithm of the temperature are connected by the statistical relation

$$B + 1{\cdot}9\, B_s = \text{constant}$$

where $$B_s = -\ 10 \log \theta.$$

This equation may be regarded as the equation of the Cepheid branch of the Russell-Hertzsprung diagram, i.e. as the equation of the locus of the equilibrium states which make up the Cepheid variables. If the above equation be compared with the relation $r\theta =$ constant which can be written in the form $2\,B = -\ B_s +$ constant, we see that the curves in the (B, B_s) plane represented by the above two equations are orthogonal, within the limits of error of determination of the constants, i.e. the oscillations in B and log θ of a Cepheid variable are such as to cause the representative point in the (B, log θ) plane to oscillate along a line which is normal to the equilibrium locus of the variables.

This behaviour is typical of oscillations about a state of equilibrium, and must be considered of importance in favour of the view that the phenomena of Cepheid variability involve some form of such an oscillation about equilibrium. The present

evidence appears to be the most important so far put forward in favour of the pulsation theory, with the exception of that of the period-luminosity-spectrum relation.

CHAPTER 9.—THE PERIOD-LUMINOSITY-SPECTRUM RELATIONS.

16. It has long been known that the period and the luminosity and that the period and median spectral class of a Cepheid variable are strongly correlated, the former correlation being the more strongly marked. I have shown (16) that the two relationships may be combined into a single equation, the period-luminosity-spectrum relation. If instead of the visual or photographic magnitude we substitute the bolometric magnitude, and instead of the spectral type we use the logarithm of the temperature, or more conveniently the bolometric magnitude for unit surface, B_s, defined by the relation $B_s = - 10 \log \theta$, then the period-luminosity-spectrum relation can be expressed by the equation

$$2 \log P + 0{\cdot}48\ B - 0{\cdot}58\ B_s + 1{\cdot}98 = 0. \quad . \quad . \quad (16.1)$$

In order to show the fit of this formula to the observations, we give in Table 9, I, the values of the constant

$$K = 0{\cdot}48\ B - 0{\cdot}58 B_s + 2 \log P + 1{\cdot}98$$

calculated for the mean values of log P, B, and B_s for various groups of stars, taken from a table by Shapley (17).

TABLE 9, I.

Mean log P	No. of Stars	Mean Ph. Mag.	Mean Type	Mean B_s	Mean B	K
0·206	19	−0·74	F 5·8	−0·47	−5·65	−0·01
0·610	53	−1·24	G 0·0	0·19	−6·47	−0·01
1·105	34	−2·06	G 5·0	0·87	−7·64	0·02

The same relation appears to hold also for the long period variables, but the correction to bolometric magnitude for these bodies is not yet very well known, and the agreement cannot be stressed at this stage.

The interpretation of the equation (16.1) in the light of the period-density relation predicted for the Cepheids is not far to seek. Taken in conjunction with the relation

$$2 \log P + \log \rho_m = \text{constant} \quad . \quad . \quad (16.2)$$

the equation (16.1) leads to an expression for the mean density of a Cepheid,

$$\log \rho_m = 0{\cdot}48\ B - 0{\cdot}58\ B_s + \text{constant} \quad . \quad . \quad (16.3)$$

which can be tested directly in the case of stars for which the density is known. In order to test the validity of this relation, I have made use of the table of first class determinations of

stellar masses given by Eddington (18). Eddington's Table 17 gives the masses, bolometric absolute magnitudes, and temperatures of a number of stars. The mean densities can then be calculated from the observed data by the relation

$$\log \rho_m = \log \mu + 0{\cdot}6\ (B - B_s)$$

and then compared with the values obtained from equation (16.3). The results of the comparisons are given in Table 9, II.

TABLE 9, II.

Star		Log Mass	B	B_s	Log ρ_m Obs.	Log ρ_m Calc.	O − C
Capella	b	0·621	−5·21	+0·43	−2·763	−2·750	−0·013
	f	0·521	−4·63	−1·10	−1·597	−1·595	−0·002
Sirius	b	0·389	−3·88	−2·62	−0·367	−0·342	−0·025
α Cen	b	0·057	−0·32	+0·60	−0·495	−0·502	+0·007
	f	−0·013	+0·39	1·91	−0·925	−0·921	−0·004
Sun		0·000	0·00	0·00	0·000	0·000	0·000
Krueger	60b	−0·569	4·97	2·67	+0·811	+0·835	−0·024
	f	−0·796	7·57	2·67	2·084	2·035	+0·049

The calculated and observed densities are reduced to the sun as unit, and the agreement between the observed and the calculated values, given in the last column as observed-minus-calculated, is very striking. Over a range of densities varying through a factor of a hundred thousand, the maximum difference between observed and computed density is less than 5 per cent. of the observed value, and in the other cases the agreement is still closer.

We therefore conclude that the observed period-luminosity-spectrum relation is the expression of the period-density law. As we have seen, however, the period-density relation is a common feature of most dynamical theories of Cepheid variation, and the test between rival theories lies in the exact value of the constant in the period-density relation. It can, however, be shown that the pulsation theory in the Eddington form does predict the exact numerical value of this constant.

The period of the fundamental pulsation is given by Eddington's theory by the equation

$$\pi \sqrt{\rho_c} = 0{\cdot}290\ (\gamma\alpha)^{-\frac{1}{2}} \qquad . \quad . \quad (16.4)$$

where π is the period, ρ_c is the central density, γ is the effective ratio of the specific heats, and $\alpha = 3 - 4/\gamma$. It is, however, undoubtedly better to use the mean density, ρ_m, instead of the central density ρ_c, since the mean density is determinable with the help of the mass-luminosity relation, whereas the central

density is not known until one knows the polytropic index n, or the equivalent ratio of the specific heats γ, according to which the star is built.

The transformation from the above equation to the corresponding relation for the mean density, for various values of the polytropic index n, is given in Table 9, III. The data are taken from the relevant portions of Eddington's "Internal Constitution of the Stars." It is clear that over the relevant range of the effective ratio of the specific heats, between, say, 1·40 and 1·66, the predicted value of $\pi\sqrt{\rho_m}$ is very closely given by 0·12, a value which we shall therefore assume in order to compare the theory with observation.

TABLE 9, III.

n	γ	α	ρ_c/ρ_m	$\pi\sqrt{\rho_m}$
1·5 ...	1·667 ...	0·6 ...	6·00 ...	0·1184
2·0 ...	1·5 ...	0·333 ...	11·40 ...	0·1211
2·5 ...	1·4 ...	0·14 ...	24·08 ...	0·1313

For Delta Cephei (I.C.S., p. 182), we have $\rho_m = 0{\cdot}00502$, whence, from the period-density relation

$$\pi\sqrt{\rho_m} = 0{\cdot}12$$

we find the theoretical period 5·35 days. The actual period of Delta Cephei is 5·366 days, so that the pulsation theory predicts the period of a Cepheid with complete accuracy.

17. The correlations between period and luminosity on one hand, and period and spectral type on the other, can, as I have recently shown (10), be represented by the relations

$$B = -2{\cdot}7 \log P - 5{\cdot}28 \qquad . \quad . \quad (17.1)$$

$$B_s = 1{\cdot}4 \log P - 1{\cdot}04 \qquad . \quad . \quad (17.2)$$

respectively. In addition, there appears to be quite a marked relation between luminosity and spectral type, given by

$$B + 1{\cdot}9\, B_s + 7{\cdot}25 = 0 \qquad . \quad . \quad (17.3)$$

the probable error of the coefficient of B_s being $\pm$ 0·18 for the material used. This latter relation may be regarded as the expression of the Cepheid branch of the Russell-Hertzsprung, and together with the period-luminosity-spectrum relation (16.1) can be used to derive the individual relations (17.1), (17.2). Equations (16.1) and (17.3) must therefore be regarded as fundamental, and the correct interpretation of (17.3) must probably await a satisfactory theory of the cause of stellar variability. As a purely empirical relation, however, it must be explained by any successful theory of Cepheid variability. It is not intended to attempt this problem here, but some preliminary remarks on the subject can at this stage be made.

The total heat content of a star is proportional to the gravitational potential μ^2/r, where μ is the stellar mass. By the period-density relation we have

$$P^2 \rho_m = \text{constant}.$$

We have, therefore,

$$\log H = 5 \log r - 4 \log P + \text{constant}.$$

But

$$5 \log r = B_s - B$$

and (17.1) gives

$$B = - 2{\cdot}7 \log P - 5{\cdot}28$$

Hence

$$\log H = B_s + 0{\cdot}54 \text{ B} + \text{constant}. \quad . \quad . \quad (17.4)$$

Now the relation (17.3) might be written

$$B_s + 0{\cdot}53 \text{ B} = \text{constant},$$

which agrees closely with (17.4), and may be taken to show that for the Cepheids the total heat content is constant.

Further, the relation H = constant may be written

$$r^5 \propto P^4$$

i.e. $5 \log r - 4 \log P = \text{constant}$,

i.e. $2 \log P - 0{\cdot}50 \text{ B}_s + 0{\cdot}50 \text{ B} = \text{constant}$ . . (17.5)

which agrees fairly well with the empirical period-luminosity-spectrum relation (16.1).

This conclusion differs from that reached by Shapley (19) who decides that the average heat content per unit mass is constant for all Cepheids, i.e. μ/r is constant. If we have

$$\mu/r = \text{constant},$$

$$\text{i.e. } \rho_m r^2 = \text{constant},$$

then by the period-density relation this is equivalent to

$$r^2/P^2 = \text{constant},$$

i.e. $\log r - 2 \log P = \text{constant}$,

i.e. $\frac{2}{5} (B_s - B) = 2 \log P + \text{constant}$,

$= - 0{\cdot}77 \text{ B} + \text{constant}$,

i.e. $B_s = - 0{\cdot}93 \text{ B} + \text{constant}$,

which does not agree with the observed luminosity-spectrum relation.

Miss Payne (20) finds that the Cepheids satisfy a relation which is given roughly by

$$\rho_c = \vartheta_c^4.$$

This reduces to

$$5 \log r - 3{\cdot}8 \log P = \text{constant},$$

which agrees closely with

$$5 \log r - 4 \log P = \text{constant},$$

and reduces further to

$$2 \log P - 0{\cdot}53 \text{ B}_s + 0{\cdot}53 \text{ B} = \text{constant},$$

which also agrees closely with the empirical relation (16.1).

The fact that different interpretations satisfy the observations equally well shows that no single *ad hoc* interpretation should be stressed. The theoretical explanation of the luminosity-spectrum relation remains at present one of the most important problems in the theory of stellar variation.

The period-luminosity-spectrum relation appears to have been first given by Nikonow and Zessewitsch (21). Using Jeans' mass-luminosity formula

$$\mu \; a \; L^{1/3 \cdot 4} \; a \; L^{0 \cdot 29}$$

and the period-density relation, they derive the formula

$$\log P + 0{\cdot}24\ B + 3 \log T = \text{constant}$$

which agrees very well with (16.1). They then showed that this formula fitted the observations very well, for periods varying from $\log P = -0{\cdot}32$ to $\log P = +2{\cdot}65$, i.e. the period-luminosity-spectrum relation holds for all types of what the authors call "thermal variables." Nikonow and Zessewitsch then conclude, however, that this must be regarded as evidence in favour of Jeans' fission theory of Cepheid variability, a conclusion which in the light of the present investigation seems unfounded.

To summarise, the present investigation shows that:

(i) the Cepheid and long period variables satisfy a relation which is identical with the period-density relation,

$$2 \log P + 0{\cdot}48\ B - 0{\cdot}58\ B_s + 1{\cdot}98 = 0;$$

(ii) and the constant in this relation agrees completely with that predicted by Eddington on the basis of the pulsation theory.

(iii) Between B and B_s there exists a fairly close statistical relationship, given by the equation

$$B + 1{\cdot}9\ B_s + 7{\cdot}25 = 0.$$

Chapter 10.—Statistical Relations in the Long Period Variables.

18. A considerable number of statistical relationships have been found to exist in the long period variables, details of which are given in Ludendorff's comprehensive monograph (22), and in Thomas's dissertation (23). The most important, however, appear to be those connecting the period, the spectral type at maximum, and the amplitude of light variation, all of which are similar to corresponding correlations found in the Cepheids. The investigations of the present Chapter depend on the material in the Harvard catalogue of long period variables (24), together with a number of stars for which data have subsequently been given by Miss Payne (25).

From the material thus available, I have computed the coefficient of correlation between period and spectral type for the stars of spectral class Me, with the results given in Table 10, I.

TABLE 10, I.

Characteristic		Harvard Cat.	Payne	Combined
Mean Period ...	...	298·0 d	289·0 d	296·1 d
Mean Type ...	...	M 4·433 e	M 4·506 e	M 4·449 e
S.D. of Period	...	87·3 d	83·2 d	86·1 d
S.D. of Type	...	1·596	1·549	1·586
Corr. Coefficient	...	0·778	0·653	0·756
		± 0·016	± 0·043	± 0·015
Number of Stars	...	300	81	381

It is clear, therefore, that there is a marked correlation between period and type at maximum in the Mira variables, as in the Cepheids, and Shapley has, in fact, shown that the same relation holds throughout for both classes (26).

The relation between period and amplitude has also been known for a considerable time. The material of the Harvard catalogue has here been used to compute the correlation between the period and the visual amplitude. The relation of period to photographic amplitude has been studied from Miss Payne's material, with the results given in Table 10, II.

TABLE 10, II.

Characteristic		Visual Amplitude	Photographic Amplitude	Se Stars
Mean Period ...	...	298·0 d	289·0 d	370·0 d
Mean Amplitude	...	4·712 m	3·679 m	4·757 m
S.D. of Period	...	87·29 d	83·2 d	84·7 d
S.D. of Amplitude	...	1·076 m	1·160 m	1·367 m
Coefficient of Corr.	...	+ 0·381	0·101	0·184
		± 0·033	± 0·074	± 0·14
Number of Stars	...	300	81	21

The coefficient of correlation appears to be significant in the case of the visual amplitude of stars of class Me, but not when photographic amplitudes are considered for this spectral class, nor when visual amplitudes are considered for stars of spectral class Se, as given in the last column.

The third relation, between spectral type and amplitude, though not so well marked as the previous two, has also been noticed. The results of the present investigation are given in Table 10, III. In neither case does the correlation appear to be significant.

TABLE 10, III.

Characteristic	Visual Amplitude		Photographic Amplitude
Coefficient of Correlation ...	+ 0·161	...	− 0·103
Probable Error	± 0·04	...	± 0·07
Number of Stars	300	...	81

The present results agree with the tentative conclusions of a previous investigation, based on a smaller material (27). It appears that period is correlated with spectral type at maximum, and with visual amplitude, but that the type is *not* correlated with the amplitude. These conclusions are strengthened by the further evidence of the partial coefficients of correlation, given in Table 10, IV.

TABLE 10, IV.

Variables	Constant	Coefficient	Probable Error
Period, Type ...	Amplitude	+ 0·784	± 0·01
Period, Amplitude ...	Type ...	+ 0·412	± 0·03
Amplitude, Type ...	Period ...	− 0·238	± 0·04

In the case of the Cepheids, we found that period and type, and period and amplitude were definitely correlated when other variables are kept constant, but that it was doubtful whether amplitude and type are correlated. Then present results for the long period variables. therefore, serve to bring out the close relationship between the two classes of variables.

CHAPTER 11.—THE ORIGIN OF THE EMISSION LINES IN THE SPECTRA OF LONG PERIOD VARIABLES.

19. In order to explain the phenomena of stellar variability we have postulated the existence of body pulsations of the star, which give rise to periodic changes in the photospheric radius and temperature, in such a way that as the observations of the Cepheids have shown, maximum photospheric temperature occurs at minimum radius and vice versa. These body pulsations are not transmitted unchanged to the stellar atmosphere; through some mechanism such as convection currents, or, particularly in the case of the chromosphere. by increased selective radiation pressure, the gases in the atmosphere are driven upwards with a considerable velocity. The greatest upward velocity occurs at some phase shortly after maximum light, i.e. at the stage of greatest compression of the star. At the same time, downward currents of cooler gas may be set up.

The reality of this process in non-pulsating stars has been placed beyond doubt by the well-known work of St. John and

Adams, who have shown that there is an upward motion in the low-, and a downward motion of the high-level lines in stars such as Sirius, Procyon, Arcturus, and the Sun. Their observations show that there is a dependence of the intensity of the convection currents on the temperature of the star. They also show that the differences Enhanced-minus-arc lines for Delta Cephei are the largest found for any of the stars investigated, amounting to 2·4 km./sec. at maximum light, and 0·9 km./sec. at light minimum. "The presence of strong convection currents in a variable star of this class is very probable, especially if the pulsation theory of the cause of the variability is accepted." (28).

It is difficult to estimate the velocity which a pure convection current is likely to attain in a long period variable, but it seems likely that they can be considerably greater than the currents of magnitudes of a few kilometres per second that are observed in non-variable giant stars.

In addition there is the possible effect of selective radiation pressure. Assuming the Milne type of chromospheric equilibrium, consisting of a balance between the upward increase of momentum due to the absorption of light quanta and the downward impulse of gravity in the same time, it is clear that an increase in the photospheric temperature must disturb the chromospheric equilibrium. The atoms will then proceed to move upwards with steadily increasing velocity, which can become very large, as Milne has shown.

In practice, the increased emission from the photosphere in the line concerned will drive off a number of atoms which would otherwise lie low in the atmosphere, and thus interpose an absorbing screen between the photospheric layers, cutting down the residual intensity in the line when the light reaches the true chromosphere. The effect of an increase in the temperature of the photosphere would therefore be an increase in the photospheric mass, and also in the upward velocity of the chromospheric layers. We should therefore expect maximum velocity to occur at some time after maximum light.

The phase relation is also shown by the following argument. For a chromosphere supported in accordance with Milne's theory, and in equilibrium at a given temperature, then if the temperature were to change, the upward acceleration would coincide in phase, or follow slightly, the rate of change of temperature of the photosphere.

The bright lines observed near maximum in the Mira variables are members of the Balmer series, and several lines of the ionised metals, all of which occur at relatively high levels in the solar chromosphere. With the ultimate lines of several elements appearing in emission near minimum light, we are at present not concerned.

20. Our problem is now to account for the occurrence of these lines in emission rather than in absorption. Although there

are several other possibilities, such as the thermal excitation of the atoms by the heated gases rising from below, and the effect of local electric fields and the gravitational field in giving charged particles energy which can be lost by inelastic impact, there appears to be one main method by which a chromospheric line may occur in emission, originally investigated by Rosseland (29). Rosseland has shown that a line will appear in emission if the total optical depth of the layer from which it originates is small, in absorption if the optical depth is large. Thus the condition for the appearance of emission lines in the integrated spectrum of the radiation emitted from a gaseous star in quasi-thermal equilibrium is determined by the relative extension of its atmosphere.

Near maximum light in a long period variable, the photosphere has its smallest area, while the chromospheric envelope is attaining its greatest extent. For atoms in the high layers of the chromosphere, such as those giving rise to the Balmer lines, the Rosseland effect will be the most marked, and we may expect emission for a time near maximum, since in these variables the atmospheres are enormously extended. The duration of the emission is not necessarily symmetrical about maximum light, since the two factors which determine the relative extension of the atmosphere, namely the chromospheric and photospheric radii, do not vary in the same phase. As the photospheric area increases after maximum light, the relative extension of the chromospheric layers decreases, so that the intensity of the emission also decreases, eventually giving rise to normal absorption near minimum light. The emission lines possess the radial velocity of the chromosphere.

The present theory is borne out by the fact that (i) the intensity of the emission is greater for stars in which the pulsation is most violent, and for (ii) the stars of greatest normal atmospheric extension, i.e. of smallest density, and hence of longest period, as would be expected on the above theory.

A further point of importance lies in the anomalous intensities of some of the Balmer lines, which in most cases fall in regions of strong titanium oxide absorption bands. It appears unlikely, from physical considerations, that the titanium oxide layers can be at a higher level than the hydrogen atoms, so that if the emission were due to any other cause than the one suggested here, it would be difficult to explain how the hydrogen emission could be affected by atoms lying at lower levels.

Our theory of Rosseland chromospheric emission, however, makes it clear that if a Balmer line should lie in a region of strong titanium oxide absorption, then the light from the photosphere is considerably reduced by the band absorption, and the residual intensity in the line is not then adequate to maintain the atom in its original level, thus reducing the relative extension of the Balmer chromosphere, and also the intensity of the corresponding emission.

In addition there is the further possibility that the titanium oxide layer, possessing as it does a considerable optical thickness, virtually replaces the photosphere at a higher level for the wavelengths concerned, so that the relative extension of the hydrogen layer in the chromosphere is in this way also reduced.

As the titanium oxide band intensity is reduced, the disturbing effect of the bands on the emission lines will decrease, a conclusion in full agreement with the observations. It appears, therefore, that the concept of stellar pulsations throws light on one of the most complicated phenomena in these variables.

21. If the argument of the preceding section is correct, the true stellar velocity must be midway between that of the upward moving emission lines and the downward moving absorption lines. A test of this hypothesis is provided by a discussion of the radial velocities. The K-term, as computed from the true stellar velocity, should be relatively small; that computed from a velocity which is systematically larger or smaller than the true velocity should be large, positive or negative, respectively.

Merrill has shown that from 83 long period variables for which the emission velocities are known, the K-term is − 11·7 km. sec. (30). On the other hand, Miss Allen has shown for 63 stars for which absorption lines were measured that the K-term in this case is + 9 km./sec. (31). From 132 stars for which the stellar velocity was taken to be the mean of the emission and absorption velocities at maximum light, I have shown that the K-term is + 3 km./sec. (32), which agrees well with the value found for non-variable M stars, and points to the essential correctness of the views expressed above.

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NEUE GEOPHYSIKALISCHE BEZIEHUNGEN DER METEORE

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Die Erforschung der Meteore, jener Erscheinungen, die ganz allgemein durch das Eindringen kosmischer Körper in die Erdatmosphäre hervorgerufen werden, hat in den letzten Jahren einen Aufschwung genommen, der noch vor kurzer Zeit nicht abzusehen war. Zwei Ursachen kommen dafür in erster Linie in Betracht: die Feststellung vom Jahre 1922, dass unter den kleinen, die Erscheinung der Sternschnuppen veranlassenden Meteorkörpern eine sehr grosse Anzahl solcher ist, die sich in hyperbolischen Bahnen durch das Sonnensystem bewegen, also nicht, wie man bis dahin angenommen hatte, kometarischen Ursprungs sein können, und die etwa um 1924 beginnenden Versuche, aus Ergebnissen der Meteorforschung auf Zustände der oberen Atmosphärenschichten zu schliessen. Dabei erwies sich der erste, rein astronomische Impuls zunächst als ungleich stärker, weil er unmittelbar zu einer Reihe neuer Fragesstellungen und zum Teil auch nach verhältnismässig kurzer Zeit zur Beantwortung dieser Fragen geführt hat. So kann es heute bereits als eine nahezu gesicherte Feststellung gelten, dass die Bewegungsrichtungen jener „interstellaren," d.h. aus dem Fixsternraum kommenden Meteorkörper nicht gleichmässig im Raume verteilt sind, sondern dass eine Strömung dieser Materie etwa vom Taurus gegen den Scorpius hin besteht und dass die dadurch nahegelegte Beziehung zu den grossen Dunkelwolken, die in beiden Richtungen uns das Licht der Milchstrasse zum Teil abdecken, nicht zufälliger Art ist, dass vielmehr die kleinen Meteorite ein Bestandteil dieser Dunkelwolken sind. Zwar haben die neueren Untersuchungen über die Schwächung und und Verfärbung des Sternlichts von Schoenberg, seinen Mitarbeitern und anderen Astronomen gezeigt, dass die Materie der Dunkelwolken zum grossen Teil viel kleinere Körper aufweist, sie haben aber zugleich ergeben, dass neben diesen kleinen Körpern auch grössere von der Art der kleinen Meteorite vorhanden sein müssen. So schlägt die Meteorforschung eine Brücke von der Erdatmosphäre zu fernen Räumen des Sternsystems.

Der zweite, in der Hauptsache durch die Arbeiten von Lindemann und Dobson gegebene Anstoss konnte deshalb nur geringere

Wirkung ausüben, weil sich die Erörterungen vielmehr im Bereich des Hypothetischen bewegen mussten. Bis zur Gegenwart ist darin kein wesentlicher Fortschritt erzielt, trotzdem inzwischen eine Reihe von Arbeiten über das Thema erschienen ist. Man gewinnt vielmehr den Eindruck, dass mehr Fragen gestellt als beantwortet sind, und dies ist auch begreiflich angesichts der ganz ausserordentlichen Schwierigkeiten, die allein das Problem des Leuchtens der Sternschnuppen und der dabei auftretenden Verwandlung von kinetischer Energie in andere Energieformen darbietet. So kann man verstehen, dass, solange das Grundproblem nicht befriedigend gelöst ist, auch nicht viel Licht auf Nebenumstände, wie sie die Verhältnisse der oberen Luftschichten darstellen, fallen kann. Wesentlich ist aber, dass durch die bisherigen Arbeiten die Wege gezeigt sind, auf denen man zum Ziel gelangen kann, sobald die erwähnten Voraussetzungen erfüllt sein werden, und es ist deshalb nicht schwer, vorauszusagen, dass die Meteorforschung für die Erforschung der oberen Luftschichten einst noch zu grosser Bedeutung gelangen wird.

In einer Hinsicht ist dies aber schon seit langer Zeit der Fall: die Meteore, genauer gesagt: die von ihnen in der Erdatmosphäre erzeugten Wolken leuchtenden Dampfes, stellen vorläufig das einzige Mittel dar, das uns Aufschluss zu geben vermag über Luftströmungen in Höhen von etwa 100 km. Ich will auf die Ergebnisse hier nicht eingehen, sondern nur eine kürzlich an der etwa eine Stunde lang sichtbaren Leuchtwolke eines am 23. Juli 1936 über Deutschland erschienenen Meteors gemachte Erfahrung anführen, wonach zwischen 90 und 95 km Höhe eine Sprungschicht des Windes mit einer Drehung um 90° etwa von West auf Süd bestand. Auch in diesen grossen Höhen ist also offenbar noch Turbulenz vorhanden, und wir werden weiter unten sehen, dass dies wahrscheinlich auch noch für sehr viel grössere Höhen gilt.

Hier soll nun über einen neuen Zweig der Forschung im astronomisch-geophysikalischen Grenzgebiet berichtet werden. Es ist eine bekannte Erfahrung, dass der klare, mondlose Nachthimmel nicht immer gleich dunkel ist, dass vielmehr manchmal, und gar nicht sehr selten, ausgesprochen helle Nächte auftreten. Auch in der wissenschaftlichen Literatur ist diese Erscheinung, meist unter der Bezeichnung ,, Heller Nachthimmel " oder " Luminous Night Sky " immer wieder beschrieben worden. Berichte aus früheren Jahren liegen unter anderem vor von Maurer in Zürich, von Wolf in Heidelberg und von den Beobachtern der British Astronomical Association, aber niemals ist der Versuch gemacht worden, die Erscheinung planmässig zu verfolgen, was allerdings in dem ungünstigen Klima Mitteleuropas auch recht schwierig ist. Vielfach hielt man die Erhellungen auch einfach für schwache Polarlichter und schenkte ihnen deshalb nicht mehr Beachtung, als diesen zukam. Zufällige Erfahrungen aus den Jahren 1915 bis 1921 legten mir

indessen die Vermutung nahe, dass die Erscheinung doch möglicherweise ganz anderer Art sein könne und veranlassten planmässige Beobachtungen auf der für diesen Zweck sehr günstig gelegenen Sternwarte zu Sonneberg. Selbstverständlich durften erst aus langjährigen Reihen Ergebnisse abgeleitet werden, bis sich die Zufälligkeiten des Wetters und des Mondwechsels einigermassen ausgeglichen hatten, aber jetzt ist die Zeit gekommen, einige allgemeine Züge aus den Beobachtungen abzulesen.

Das erste Ergebnis ist die Feststellung eines jährlichen Ganges der Häufigkeit und Intensität der Erscheinungen derart, dass ein tiefes Minimum im April, hohe Maxima im August und der ersten Septemberhälfte sowie im November und Dezember auftreten. Diese Feststellungen gelten zunächst nur für 50° Nordbreite. Eine weitere, für die Erklärung sehr wichtige Feststellung betraf die Häufung der Erscheinungen um die Daten einiger kometarischer Meteorströme. Inbesondere waren die August-Perseiden, der stärkste Strom der Nordhalbkugel, die Leoniden im November und die Geminiden um Mitte Dezember fast regelmässig durch Erhellungen des Himmels ausgezeichnet. Dabei war bemerkenswert, dass die Erhellungen unabhängig von der Meteorzahl auftraten, was besonders bei den Leoniden, die ja hinsichtlich der Meteorzahlen bei der erwarteten Wiederkehr um 1934 stark enttäuscht haben, auffällig war, denn diese Wiederkehr brachte die stärksten Erhellungen, die ich jemals beobachtet habe. Auch für einige weitere Meteorströme ist die Beziehung nachgewiesen. Anderseits sind z.B. die Lyriden vom April bisher immer ohne Erhellungen geblieben, wie auch nicht wenige Erhellungen sich um Daten häufen, für die bisher keine Meteorströme nachgewiesen werden konnten. Indessen ist die Beziehung in den angeführten Fällen so eindeutig, dass sie nicht übergangen werden darf.

Im Jahre 1934 legte mir Prof. Zenneck von der Technischen Hochschule in München die Frage vor, ob gewisse von ihm beobachtete Störungen der Ionisation hoher Schichten durch Einwirkung von Meteoren zustandekommen könnten. Die Nachprüfung ergab keine Beziehung zur Anzahl der Meteore, dagegen eine deutliche Verwandtschaft mit den hochatmosphärischen Erhellungen, die sowohl im jährlichen Gang als auch in einer Reihe von Einzelfällen zum Ausdruck kam. Einwirkungen der Meteore auf den Zustand der Ionosphäre waren verschiedentlich vermutet worden. Einander entgegen standen die Ansichten von Skellett, der die ionisierende Wirkung der Meteore betonte, und von Nagaoka, der das Hauptgewicht auf die durch Ionenbindung entionisierende Wirkung des von den Meteoren zurückgelassenen Staubes legte. Inwieweit sich beide Wirkungen gegenseitig ausgleichen, ist schwer abzuschätzen, ist auch hier ohne Belang, denn hier handelt es sich gar nicht um direkte Wirkungen der Meteore, sondern um Begleitumstände der als Parallel-Erscheinungen von Meteorströmen auftretenden Erhel-

lungen. Wesentlich ist aber, dass—bei den von Zenneck vorgelegten Fällen in der Mehrzahl um Verminderungen der Ionisation festgestellt worden.

Auf diesen Grundlagen habe ich die Hypothese entwickelt, dass die beschriebenen Erscheinungen durch Einbrüche kometarischen Staubes in die oberen Schichten der Erdatmosphäre verursacht werden.

Man muss dabei annehmen, dass neben den Meteorkörpern auch noch Massen von viel feinerer Struktur von den Kometen längs ihrer Bahnen ausgestreut werden. Meteorstrom und Staubstrom brauchen dabei räumlich nicht zusammenzufallen. Dass dies nicht allgemein stattfindet, wird durch die Erfahrungen am Leonidenstrom nahegelegt. Jedenfalls können auf dieser Grundlage die bisher beobachteten Erscheinungen erklärt werden; im übrigen ist auf diesem Gebiete noch fast alle Arbeit zu tun. Der gegenwärtige Aufenthalt des Verfassers in Windhuk dient in der Hauptsache dem Zweck, Beobachtungen und Erfahrungen zu dem hier behandelten Thema zu sammeln, und es kann jetzt schon mitgeteilt werden, dass bereits wertvolle Aufschlüsse erlangt werden konnten. Erwähnt sei zunächst die Feststellung, dass die Erhellungen auch hier auf der Südhalbkugel und in niederen Breiten auftreten. Dies war keineswegs sicher, denn es war mit der Möglichkeit der magnetischen Ablenkung des wahrscheinlich elektrisch nicht neutralen Staubes nach höheren Breiten zu rechnen. Ferner gelang der Nachweis, dass auch der stärkste Meteorstrom der Südhalbkugel, die mit dem Halley-schen Kometen in Zusammenhang stehenden, in der ersten Maihälfte auftretenden Aquariden, mit Erhellungen verbunden ist. Das Klima von Süd- und Südwest-Afrika ist für derartige Untersuchungen, die nach Möglichkeit beständig klaren Himmel bei guter Durchsicht erfordern, so gut geeignet wie kaum ein anderes. Indessen soll auch der Hinweis nicht unterlassen werden, dass es nicht jedem Beobachter ohne weiteres gelingen wird, die in Frage stehenden Erscheinungen zu erkennen und richtig zu deuten. Die Erfahrung hat gezeigt, dass es für das Zustandekomen einwandfreier Beobachtungen einer sehr gründlichen Vertrautheit mit allen Erscheinungen des Nachthimmels, vor allem auch dem Zodiakallicht und der Dämmerung, bedarf, wie sie in der Regel nur durch langjährige Beschäftigung mit dem Gegenstand erworben werden kann.

Die Erhellungen sind meist recht schwach. Sie treten sowohl als diffuse Lichtscheine am Horizont, als nach oben stufenartig scharfbegrenzte Bänke wie auch in der besonders kennzeichnenden Streifenform, und dann meist als Strahlenfächer mit Konvergenz nach einem im Horizont liegenden Punkte hin auf.

Es ist bisher nicht gelungen, die Erscheinung so zu photographieren, dass die Aufnahmen für Messzwecke geeignet wären. Daher liegen auch noch keine einwandfreien Höhen-

bestimmungen vor. Man kann aber aus verschiedenen Gründen vermuten, dass die Höhe gross ist, dass die Erscheinung vielleicht der F-Schicht der Ionosphäre bei etwa 200 km Höhe, vielleicht auch einer noch höheren Schicht angehört. Neben den Beziehungen zur Ionisation dieser Schichten spricht dafür die auf höheren Breiten gemachte Wahrnehmung, dass manchmal aber keineswegs in allen Fällen, reflektiertes Sonnenlicht bei den Erhellungen mitwirkt. Man beobachtet dann ein Wandern der hellsten Stelle am Horizont mit dem Azimut der Sonne.

Bemerkenswert sind die Bewegungen der Leuchtstreifen. In der Regel ist mindestens die Komponente senkrecht zur Längsrichting der Streifen leicht zu beobachten. Die Bewegungen sind langsam, von der Grösse von 1 Bogengrad in der Minute. Sobald es gelingt, einwandfreie Höhenbestimmungen auszuführen, besitzen wir in den Beobachtungen der Leuchtstreifen ein neues und das erste Mittel, Strömungen der Atmosphäre in Höhen von weit über 100 km zu bestimmen. Einige qualitative Angaben lassen sich heute schon auf Grund der umfangreichen Sonneberger Beobachtungen machen: 1. Es ist keine Bewegungsrichtung besonders bevorzugt; es hat also den Anschein, dass auch in jenen grossen Höhen die Atmosphäre an der Erdrotation voll teilnimmt. Diese Erfahrung widerspricht u.a. auch der Annahme von Leithäuser, dass die Ionosphäre an der Rotation nicht beteiligt sei. 2. Man beobachtet gelegentlich gleichzeitig mehrere Systeme von Leuchtstreifen mit verschiedenen Konvergenzpunkten und verschiedener, manchmal entgegengesetzter Bewegung. Es ist anzunehmen, dass diese Systeme verschiedenen Höhenschichten angehören, und gleichzeitig ist gezeigt, dass auch in jenen grossen Höhen noch Windschichtung auftritt.

Darauf deutet auch die Anordnung des Leuchtens in Streifen form hin, die wie bei den Cirren doch kaum anders zu erklären ist als durch Wellenbildung an einer Sprungschicht, freilich ohne Heranziehung von Kondensation. Im übrigen lässt sich darüber noch nichts aussagen, und man muss sich darauf beschränken, die Erklärungsmöglichkeiten anzudeuten.

Es ist eine bekannte Tatsache, dass das Himmelslicht auch zu den Zeiten normalen Zustandes einen gewissen Anteil enthält, der als Eigenlicht der Atmosphäre anzusprechen ist. Dies ist u.a. bewiesen durch das Auftreten der bekannten grünen Nordlichtlinie λ 5577 Å, auch ohne dass Polarlichter beobachtet werden. Man hat daraus auf ein ständiges sehr schwaches Polarlicht geschlossen.

Meine Beobachtungen in Windhuk legen nun eindringlich den Schluss nahe, dass Leuchtstreifen und Heller Nachthimmel nichts anderes sind als eine Uebersteigerung des Normalzustandes der Atmosphäre. Demnach wären also die „ungewöhnlichen" Erhellungen und das „normale" Eigenlicht der Hochatmosphäre von derselben Art und auf dieselbe Ursache

zurückzuführen. Dies widerspricht vollkommen der bisherigen Annahme über die Natur des Eigenlichts, denn es muss betont werden, dass die Leuchtstreifen keinerlei Beziehung zu magnetischen Vorgängen verraten, folglich auch auf keinen Fall als eine besondere Form des Polarlichts angesprochen werden dürfen. Wichtig ist hier das Verhalten der grünen ,, Polarlichtlinie,'' die im Spektrum des Nachthimmels höherer Breiten beständig auftritt, die aber auch, soweit ich durch gelegentliche Mitteilungen unterrichtet bin, von Schoenberg auf der Sternwarte zu Windhuk in etwa derselben Intensität beobachtet sein soll. Jedenfalls kann ich aus eigener Erfahrung bestätigen, dass der Himmel in Windhuk nicht etwa dunkler ist als man ihn unter vergleichbaren Umständen in Europa findet. Dies legt die Vermutung nahe, dass die Linie λ 5577 Å im normalen oder gesteigerten Eigenlicht der Atmosphäre nicht als Kennzeichen eines Polarlichts angesehen werden darf, also nicht durch Kathodenstrahlen der Sonne, sondern durch irgendwelche andere Ursachen angeregt wird.

Aufnahmen des Spektrums der Leuchtstreifen liegen noch kaum vor. Immerhin scheint es, dass Dufay in Lyon bei seinen Beobachtungen des Nachthimmel-Spektrums auch gelegentlich unbeabsichtigt das Spektrum von Erhellungen erhalten hat. Die einzige beabsichtigte Aufnahme scheint eine solche von Götz in Arosa zu sein, wobei die Intensität der 3 ,, normalen '' Emissionen 4100, 4500 und 5577 Å gleichmässig auf den zwei- bis dreifachen Wert angestiegen war. Auch dieses Ergebnis ist der oben mitgeteilten abweichenden Deutung der grünen Linie günstig. Immerhin muss man dabei vorsichtig sein, weil solche Intensitätssteigerungen, wenn auch wohl kaum in dem beobachteten Umfange, auch durch photographische Wirkungen, etwa durch eine Art der Vorbelichtung durch ein unterschwelliges Kontinuum, erzeugt werden können. Darauf ist u.a. auch bei Spektralaufnahmen des Zodiakallichts besonders zu achten.

Es scheint nunmehr möglich, auf Grund der vorstehend mitgeteilten Gedanken eine Theorie des Eigenlichtes der Atmosphäre aufzustellen, eine Theorie, die vorläufig keinen anderen Zweck haben soll, als den, eine Vergleichung mit den Beobachtungen zu ermöglichen, wobei sich zeigen wird, ob die beschriebenen Vorgänge als Ursache, und vielleicht als vorherrschende oder alleinige Ursache des Atmosphärenlichtes in Betracht kommen.

Die Theorie setzt als gegebene Tatsache voraus, dass sehr kleine Körper meteoritischer Materie mit kosmischer Geschwindigkeit in die oberen, äusserst geringe Dichte aufweisenden Schichten der Erdatmosphäre eindringen. Dabei wird es zunächst erforderlich sein, zu untersuchen, welche Grössenordnungen von Körpern überhaupt in Betracht kommen mit Rücksicht auf den Strahlungsdruck der Sonne, denn Körper, die dem Strahlungsdruck unterliegen, können nicht längs der Bahn eines Kometen

wandern, sondern werden in der Richtung des Schweifes abströmen. Nehmen wir an, dass die eindringenden Teilchen in ihrer Mehrzahl so klein seien, dass gegenüber der Masse des einzelnen Teilchens die Masse des Luftmoleküls oder Atoms nicht mehr als unendlich klein angesehen werden darf, und beschränken wir uns zunächst auf Schichten äusserst geringer Luftdichte. Dann wird die gewöhnliche auf den Vorgang des Eindringens der Meteorite angewandte Betrachtungsweise nicht mehr zulässig sein. Man wird vielmehr die Zusammenstösse des eindringenden Körpers mit den Luftmolekülen als Einzelvorgänge ansehen müssen, wobei die kinetische Energie des eindringenden Körpers sprunghaft vermindert und der Körper jeweils um geringe Beträge aus seiner anfänglichen Bewegungsrichtung abgelenkt wird, wenn auch die gesamte Bahn im Mittel als Gerade angesehen werden darf. Es entsteht so dadurch, dass der Körper auf die einzelnen Zusammenstösse reagiert, eine gewisse Aehnlichkeit mit der Brown 'schen Bewegung. Die Hauptfrage, welche die vorgeschlagene Theorie beantworten soll, ist nunmehr die, was mit den von dem eindringenden Körper getroffenen Luftmolekülen oder Atomen geschieht. Insbesondere wird zu prüfen sein, ob und bis zu welcher Höhe herab Ionisation eintritt, welcher Art sonst oberhalb und unterhalb dieser Grenze die Anregung ist, welche Wellenlängen das bei der Rekombination und das infolge der Anregung ausgestrahlte Licht besitzt, welches das Intensitätsverhältnis des Rekombinations- und der angeregten Leuchtens ist und vor allem, ob sich Anhaltspunkte dafür finden lassen, dass bei diesen Vorgängen die bekannte Emission λ 5577 Å zustandekommen kann. Ferner interessiert die Frage, in welcher Höhe die eindringenden Teilchen schliesslich zum Stillstand kommen und ob sie etwa vorher wie echte Meteorite verdampft oder aufgelöst werden, was nicht unbedingt der Fall zu sein braucht. Es ist kaum abzusehen, zu welchen Ergebnissen eine solche Behandlung des Problems führen wird; jedenfalls aber scheint sie geeignet, die Verhältnisse zu klären, denn sie gestattet eine weitgehende Vergleichung mit Beobachtungen verschiedener Art.

Von Bedeutung, auch im Hinblick auf gewisse praktische Zwecke, ist die Frage, welche weiteren Einwirkungen innerhalb der Atmosphäre die hier behandelten Erscheinungen haben mögen. Ohne weiteres gegeben ist ein Einfluss auf die Ausbreitung der elektromagnetischen Wellen, die in der Nachrichtentechnik Verwendung finden, denn durch solche Wellen, wenn auch im wesentlichen bei senkrechter Ausstrahlung und Reflexion, wird nach dem von Breit und Tuve angegebenen, von Zenneck und anderen weiter ausgebildeten Verfahren der Zustand der Ionosphäre untersucht. Unvollständige Reflexion an der in etwa 80 km Höhe angenommenen E-Schicht oder der höheren F-Schicht dürfte das Hauptkennzeichen der meteorischen Störungen sein, und es ist sofort ersichtlich, dass solche Veränderungen auch auf die Ausbreitung der Wellen über grössere

Entfernungen nicht ohne erkennbare Wirkungen sein können, weil hierbei fast ausschliesslich die von der Ionosphäre reflektierten Raumwellen zur Uebermittlung der Zeichen in Betracht kommen. Hier bleibt noch fast alles zu tun, und die Untersuchung wird dadurch erschwert, dass noch eine ganze Anzahl anderer Störungsursachen gleichzeitig wirksam ist, auf dem Gebiete der Kurzwellen besonders die Sonnenstörungen und, damit zum Teil zusammenhängend, die magnetischen Störungen. Weniger aufällig für diese letzteren Einflüsse scheinen die Mittelwellen zwischen 1500 und 500 Kilohertz (200 bis 600 Meter Wellenlänge) zu sein, doch sind planmässige Versuche in diesem Bereich dadurch erschwert, dass dieser Bereich vom Rundfunk völlig in Anspruch genommen ist und Störungen des Rundfunks durch die Versuche kaum vermieden werden könnten. Immerhin kämen die Spätnachtstunden, während die Rundfunksender ausser Betrieb sind, für die Versuche in Betracht. Auch wäre zu erwägen, ob man nicht Messungen der Feldstärke und ihrer Veränderungen der Rundfunksender selbst benutzen kann. Ein Versuch des Verfassers, die Intensität und Häufigkeit des Schwundes (Fadings) einer Reihe von Rundfunksendern in einer zehnteiligen Skala zu schätzen, scheint mit aller Deutlichkeit eine Beziehung dieser Schwundzahlen zu der ober erwähnten Intensitätskurve der hochatmosphärischen Erhellungen aufzuweisen derart, dass zu Zeiten der Leuchtstreifenmaxima die mittlere Schwundzahl 6·0, zu Zeiten der Minima 4·4 betrug, wobei die Art der Berechnung aber geeignet war, die Gegensätze viel eher abgeschwächt als verstärkt wiederzugeben. Immerhin scheinen diese Zahlen auch zu zeigen, dass in den meteorischen Störungen nicht die alleinige auslösende Ursache des Schwundes zu suchen ist, wenn man auch anderseits beachten muss, dass möglicherweise, ja wahrscheinlich, die typischen Erhellungen nichts anderes sind, als Steigerungen eines beständigen Normalzustandes.

Fernerhin aber erhebt sich die Frage, wie weit die meteorischen Einwirkungen in der Atmosphäre herabreichen. So unwahrscheinlich dies zunächst aussieht, müsste man hierbei doch auch einen Einfluss auf das Wetter in Betracht ziehen. Auf welche Weise dieser zustandekommen könnte, soll dabei unentschieden bleiben und nur daran erinnert werden, dass der Atmosphäre Kondensationskerne zugeführt werden. Auch die Aenderung des elektrischen Zustandes der höchsten Schichten müsste berücksichtigt werden. Einen Hinweis auf solche Einwirkungen geben vor allem die Singularitäten. Man versteht darunter Abweichungen von den dem jahreszeitlichen Verlauf der Wetter-Elemente entsprechenden Mittelwerten, die auch in den durch langjährige Mittelbildung gewonnenen Kurven erhalten bleiben. Das schönste Beispiel dürfte in Europa die Entwicklung des Wetters in der zweiten Dezemberhälfte sein. Am 19. Dezember besteht eine starke Tendenz zur Aufheiterung; ihr folgt um den 23. bis 26., im Norden etwas früher als im Süden, ein Warmlufteinbruch mit Eintrübung, der meist zu Tauwetter

führt. Dieser Verlauf, der keineswegs alljährlich eintritt, vielmehr in manchen Jahren durch stärkere, rein meteorologische Faktoren verdeckt sein kann, ist bisher für Deutschland, die Schweiz und Mittelitalien nachgewiesen, also bereits für wesentlich verschiedene Klimate. Auch hier darf man nicht in den Fehler verfallen, alle Singularitäten auf die eine Weise erklären zu wollen. Als Singularität des deutschen Wetters erscheint z.B. auch der Monsun-Durchbruch von Ende Juni, der indessen auf ganz andere Art zu erklären ist. Aber bei jenen Singularitäten, für welche die meteorologischen Erklärungen nicht ausreichen, hat schon der Begründer der Singularitätenforschung, Schmauss in München, an die Möglichkeit kosmischer Einflüsse gedacht. Die hier dargelegte neuere Entwicklung der Meteorforschung gibt einen positiven Hinweis darauf, welcher Art solche Einflüsse sein könnten, wenngleich vorläufig alle diese Betrachtungen noch rein hypothetisch sind. Immerhin aber werden sie geeignet sein, künftiger Forschung die Richtung zu weisen.

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A STUDY OF THE CHERT OF THE DOLOMITE SERIES OF THE TRANSVAAL SYSTEM.

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With Plates I and II and 3 Text Figures.

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The main purpose of the investigation was to ascertain if the chert had any value as a raw material for the manufacture of silica refractories or in the ceramic industry. The areas investigated were the Pretoria district, from the Crocodile River to the south of Olifantsfontein; the area to the south of Johannesburg and down the Vereeniging railway line to Witkop station; the study of the former area being more detailed than of the latter.

The chert constitutes a considerable portion of the Dolomite Series, and Dr. R. B. Young (6a) states:—

"*Chertification is a prominent feature of the Dolomite Series, and, while no considerable part of its thickness is wholly unaffected by this kind of alteration, it is in the two thick shallow water phase groups, one at the very top of the series and the other not far from the bottom (Group III), that it is most conspicuous.*"

These are the general conditions of chertification. In the Pretoria area, however, an oolitic limestone in the middle of the series has been very extensively replaced by chert, and, as this feature controls the drainage of the country, this horizon may be classified as a major one of chertification.

In the Pretoria area there appear to be three main horizons of chert.

(c) Upper or Giant.
(b) Middle.
(a) Lower.

Of these the upper is the thickest and most extensive, the middle the thinnest and only well developed in this area, being thin or absent in the other areas surveyed. The upper horizon chert is almost invariably well developed (Fig. I).

Among the notable features in the chert are oolites, pisolites, breccia, carbonaceous streaking, banding, domes, and a great variation in crystal grain size.

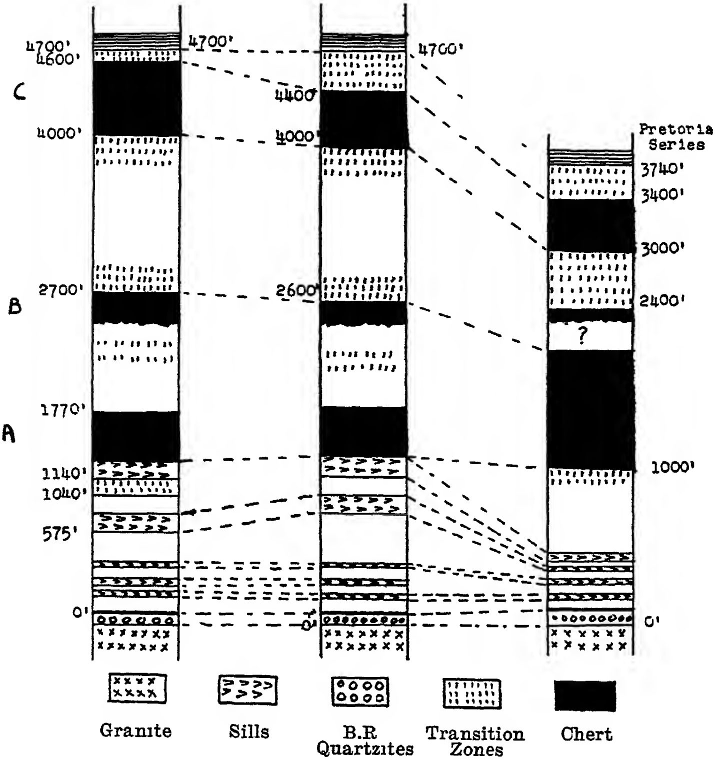


Fig. I.

A is Lower Chert Horizon.
B is Middle Chert Horizon.
C is Upper or Giant Chert Horizon.
Section I is taken from Lat. 25° 5′, Long. 28° 8′ to Lat. 25° 47′, Long. 28° 11′.
Section II is from Lat. 25° 5′, Long. 28° 8′ to Lat. 25° 21′, Long. 28° 14′.
Section III is from Lat. 25° 53½′, Long 28° 10′ to Lat. 28° 15¼′ Long. 25° 52½′.

A study was made from the following aspects:—

1. Chemical composition and variation.
2. Structures and textures.
3. Origin of chert.
4. Economic uses.

1—Chemical Composition and Variation.

The composition of the chert varies considerably within fairly wide limits as shown by the analyses. So far no specimens have been found with a silica content exceeding 99 per cent. Specimens from localities where quarrying operations could be carried

on had the compositions shown in Table I. That the content of alumina is higher than that of iron is noteworthy. In all the specimens examined this appears to be the case (1a). In thin sections no silicates such as sericite are visible, so that these constituents must be associated with the limonitic material, which is very finely disseminated. The dolomite almost invariably contains manganese, either present as the carbonate in solid solution with the dolomite and calcite or as the mixed oxide when the rock is weathered, in amounts varying from a trace to 1 or 2 per cent. in the case of some oolitic material. In the chert, however, it appears to be present only in traces and in many cases is absent. The loss on ignition has been found to be mainly hygroscopic moisture.

TABLE I.

	1.	2.	3.
SiO_2	95·00	98·30	97·70
Al_2O_3	4·47	1·85	2·25
Fe_2O_3	0·61	0·04	
TiO_2	nil	nil	nil
MnO	trace	nil	nil
CaO	0·01	0·02	0·13
MgO	0·07	0·07	0·08
Loss on ignition	0·32	0·22	0·34
	100·48	100·50	100·50
S.G. at 4°C.	2·65	2·64	2·65

1. Six Mile Spruit, Pretoria Road. (Middle chert.) Analyst, V.L.B.
2. Pelindaba Road. (Upper chert horizon.) Analyst, V.L.B.
3. Average of two cherts of the dolomite series (1).

2—STRUCTURAL AND TEXTURAL FEATURES.

A—*Structures.*

A very common and prominent feature of the chert is its brecciated nature. The size of the breccia ranges from a few millimetres to 20 or 30 centimetres mean diameter. The breccias vary considerably in thickness and strike, in some cases being parallel and in others inclined to the general strike of the dolomite.

At Hennops River where Six Mile Spruit turns abruptly northwards and then southwards, the chert is extensively brecciated, indicating two main dip faults. (See Fig. III.) In any opinion many of the brecciated zones are lines of faulting, in many cases continuing into the Black Reef or Pretoria Series. More detailed work would have to be done before these could be mapped.

The brecciated zones have been recemented by chert, often preserving original structures such as oolites (6b). Near Irene the zone of brecciation about 50-200 feet thick is parallel to the strike of the dolomite. The chert in this instance is oolitic and preserved in the recemented rock. (Plate I, No. 2.)

Near the Crocodile River and on the golf course at Irene concentric structures up to 18 inches in diameter are to be found. With regard to these structures Dr. R. B. Young states (6a):—

"*The chert sometimes exhibits an excessive contortion, apparently peculiar to itself, with the occasional appearance of abrupt swellings possessing a roughly concentric lamination.*"

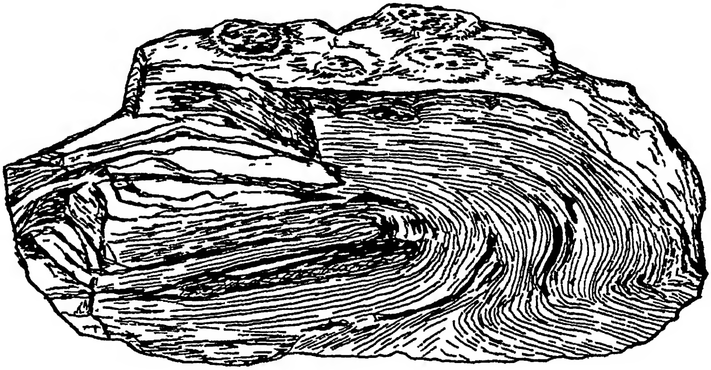


Fig. II.

Concretionary structure in Chert from the Middle horizon, near Irene, Doornkloof 499. ¾ Natural size.

Drawn by J. J. Frankel.

At Irene only isolated examples were encountered (Fig. II), but on Welgegund, where they are very prominent, these structures persist over several hundred yards, and are about four to five feet thick. These "swellings" contain intercolated layers of calcareous material. In places, however, this has been leached out by weathering. (Plate I, No. 1.)

Oolites and pisolites are very common and have been described by Dr. R. B. Young (6b). A higher manganese content seems to be associated with the oolitic dolomite or chert, but it would be difficult to apply this generally as insufficient analytical data is available. (Plate II, No. 4.)

B—*Texture.*

The chert is generally crystalline and in places has a very coarse texture (1a). Aggregates of more coarsely crystalline quartz occur in isolated patches in the more usual equigranular very fine grained material. It is difficult to account for these two great extremes of crystal grain size. The chert is mainly composed of low quartz and contains little or no isotropic material.

Any micro forms of silica are doubtful (3), and opal has not been detected at all. The quartz grains vary in size from ·005 mms. to 0·25 mms. mean diamenter, and generally possess an undulating extinction.

Large sized thin sections were cut and photographs taken by means of the method described by Shaub (2). (See Plate II, No. 2.)

3—Origin of Chert.

It was found that the chert passes through a high silica oolitic dolomite limestone into the usually blue grey platy dolomite in a distance of a few feet. The silica content of dolomite varies within wide limits, but the average of that remote from chertification would appear to be not greater than 5 or 6 per cent. The analytical data in Table II seems to support the replacement theory of the dolomite put forward by Young.

Table II.

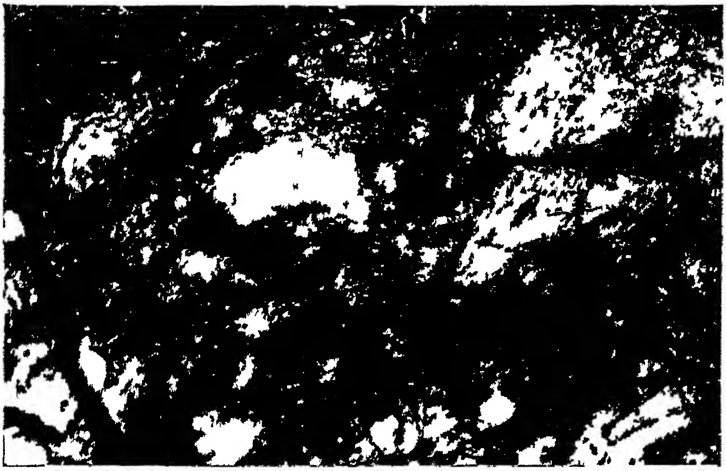
	4.	5.	6.	7.	8.	9.	10.
SiO_2	98·5	98·0	12·22	0·71	1·55	1·5	3·9
Al_2O_3	1·50 (Al_2O_3, Fe_2O_3, TiO_2)	2·34	0·05	2·50	2·10	1·8 (Al_2O_3, Fe_2O_3)	1·2
Fe_2O_3		0·19	0·90	0·09	0·10		
TiO_2		nil	nil	nil	nil	—	—
MnO	—	nil	0·26	0·47	0·44	—	—
CaO	0·38	trace	33·51	37·38	36·58	31·0	29·4
MgO	trace	nil	12·27	13·06	12·53	19·5	20·2
CO_2	—	—	—	—	—	46·1	45·2
C	—	—	nil	trace	trace	0·4	0·3
Loss on ignition	0·13	0·10	41·39	46·29	46·35	0·03	0·4
	100·41	100·63	100·60	100·51	99·65	100·33	100·5
S.G.	2·66	2·66 (1a)	2·87	2·94	2·94	—	—

Explanation of Samples.

4. Sample of chert from the middle horizon, Six Mile Spruit. Analyst, V.L.B.
5. Sample of chert from the middle horizon, Six Mile Spruit, taken 18 inches from 4. Analyst, V.L.B.
6. Oolitic cherty dolomite taken about 10 feet below the two samples above. Analyst, V.L.B.
7. Normal grey recrystallized platy dolomite about 30 feet below 6. Analyst, V.L.B.
8. Normal grey recrystallized platy dolomite in the same horizon as 7 but 50 feet away. Analyst, V.L.B.
9. Grey recrystallized dolomite from Irene Station (5).
10. Grey recrystallized dolomite from Western Witwatersrand (1b).

1. Concretionary Structures on Welgegund, near Pelindaba Chertified Platy Dolomite below × 1/12 magnification

[Photo V L B



2. Chert Breccia near Irene, Doornkloof 449. Oolites are still preserved in the Breccia × $\frac{1}{8}$ magnification.

[Photo V L B

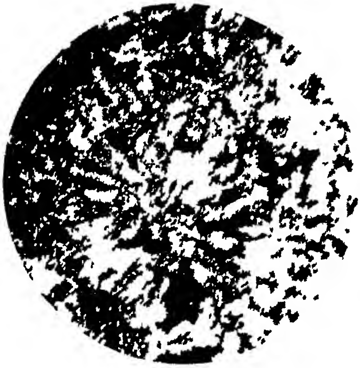
To face Page 182

1.

Chert. Showing extremely fine grained nature and mosaic texture. Magnification × 80. Crossed Nicols.

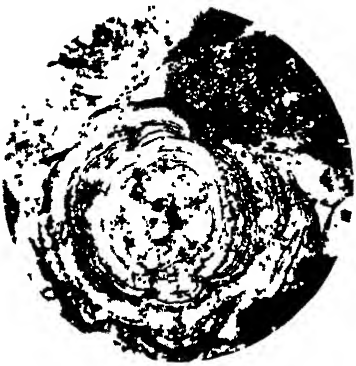
2.

Photograph showing great variation in grain size. Taken by means of "polaroid." Analyser and polariser crossed. Magnication × 4.



3.

Oolitic Dolomitic Limestone. Magnification × 30. Crossed Nicols.



4.

Oolitic Dolomite having high Manganese content. (2 – 3% MnO_2). Magnification × 25. Plane Polarised Light.

Photo micrographs 1 and 3 by L. W. Vermeulen.

Photo micrographs 2 and 4 by V. L. Bosazza.

To follow Plate I facing p. 182.

A microscopic examination of the residue of sample 6 on treatment with acid showed it to consist of low quartz of particle size 0·01 mms. diameter. No chalcedony or opal were noted, although Young records them in oolitic chert (6b). The rock is oolitic, the oolites having a radial structure. The quartz particles are not easily discernible in thin section. (Photomicrograph No. III.)

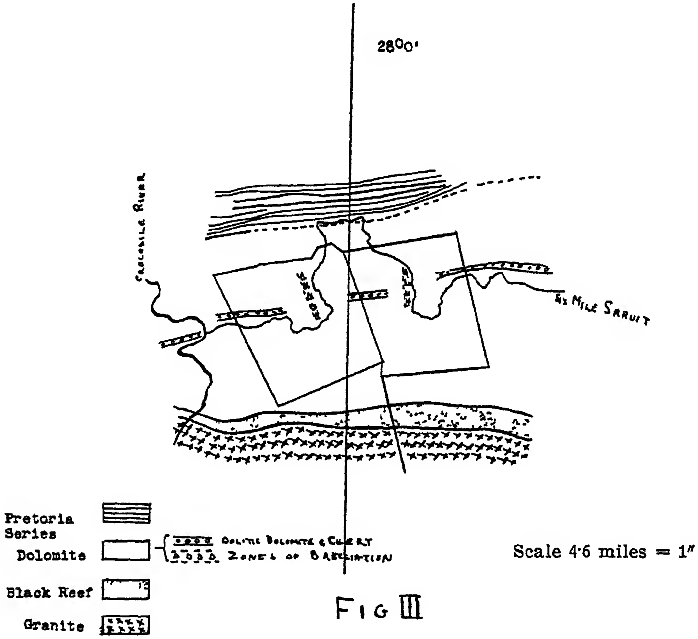


FIG III

4—Economic Uses of Chert.

In a previous paper the use of chert as a raw material for silica refractories has been discussed. This rock type is also employed in the manufacture of china ware, and was formerly employed on the Rand gold mines for tube mill linings. To-day it may possibly be used as a raw material for refractories and ceramic ware and also as an abrasive in sandpapers.

(a) *Refractories.*

The chert possesses the following properties rendering it suitable for refractory usage:—

1. Extremely fine state of crystallisation.
2. Usually high silica content.
3. Fairly high rate of conversion on heating to 1470° (1a).
4. Low porosity before and after burning (1c).
5. Fracture, even on very fine grinding, into angular particles consisting of several crystal grains (1c).

On the other hand its low iron content, fairly high alumina content, and absence of titanium dioxide are decided disadvantages. It also has a very high rate of decrepitation, which renders any ware delicate to handle on heating in a kiln. As a blend with surface quartzites, to reduce the cost of manufacture, it could be used to advantage. No definite information could be obtained that chert had at any time been used as a refractory in South Africa.

(b) *Ceramic Ware.*

Chert or flint are added to china clays to prevent shrinkage. The amounts added vary in practice, as well as the nature of the material, i.e., whether the silica is in the form of quartz, chalcedony or opal. A high silica and low iron content are essential, and the chert of the Dolomite Series possesses these features. A comparison of a water ground flint from England was made with the chert. Analyses and other data are given in Table III.

TABLE III.

	11.		12.
SiO_2	97·10	...	97·70
Al_2O_3	1·43	...	1·08
Fe_2O_3	0·51	...	0·09
TiO_2	nil	...	nil
MnO	nil	...	nil
CaO	0·02	...	0·11
MgO	0·02	...	0·10
Loss on ignition	0·42	...	0·95
	99·50	...	100·03
S.G.	2·65	...	2·44
Micrometric Analyses—			
Quartz	100	...	22
Opal	nil	...	76
Chalcedony	nil	...	2
	100	...	100

11. Chert from upper horizon. Dolomite Series. Analyst, V.L.B. Near Witkop Station, Vereeniging Railway Line.
12. Flint from chalk in England. Analyst, V.L.B.

CONCLUSIONS.

The evidence seems to be in favour of a replacement origin of the chert. Duke, as quoted by Twenhofel (4), states that in an extremely cherty formation of dolomite in Missouri, a sample of

dolomite from near the base contains 0·22 per cent. SiO_2, and one near the top 0·28 per cent. SiO_2. Similar conditions prevail in England in the chalk. These conditions are not found in the Dolomite Series in South Africa, and the evidence favours the theory put forward by Dr. Young.

From surveys made it appears that the chert and the dolomitic limestones in the areas investigated can be grouped in a similar manner to that given by Dr. Young in the case of the West Witwatersrand and Griqualand West formations. The origin of the "swelling" structures in the chert, although insufficient work has been done on the subject, appears to be mainly due to a concretionary process. The economic uses of the chert are not likely to be extensive, but it is possible that it will be employed in several ways. The possibility of its use as an abrasive in sandpapers has not been investigated.

Acknowledgments.

I gratefuly acknowledge the ever-ready assistance and interest of the Director of the Minerals Research Laboratory, Professor G. H. Stanley. I am indebted to Dr. R. B. Young, who first interested me in the subject, and also to Mr. E. Mendelssohn for discussions in the problems connected with this paper.

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INDUSTRIAL RESEARCH—THE NEED FOR CO-OPERATION

BY

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Read 6 July, 1937.

It has been said, probably with a fair amount of justification, that scientific research is the highest achievement of the human brain, and its application in industry one of the greatest factors in modern civilisation. The future prosperity and safety of nations depend largely on the extent to which they can apply scientific knowledge and method. In this paper, therefore, which describes the need for and characteristics of industrial research, we are dealing with a subject which not only affects individual industries and their development, but which is also of great significance to all sections of the community.

In its purest form, that is, "pure" as opposed to "applied," research aims at a deeper and more fundamental knowledge of things—the truth about Nature's processes and materials. The methods used to achieve this object are based on experiment and impartial observation, but the process itself is by no means simple, and requires a great deal of patience, character and intellect on the part of the experimentalist. Industrial achievement is a reflection of the application of such knowledge to industry.

The present-day industrialist, especially if he happens to be more of a business man than a technical man, does not pay too much attention to the scientific facts attained by the scientist. His success or failure will be judged on the profits of his business. Like the scientist, he might be an idealist, but his ideals, though perhaps of equal importance to our social order, lie in a different direction. He is told by the scientist—and with every justification—that research is the life-blood of industry, the basis on which all future developments and success will depend. Accordingly, he is asked to contribute funds for the purpose of obtaining such scientific data, even though its significance to his industry he is quite unable to appreciate. He is asked to reduce his profits to-day in order that he may increase them again at some future date. To him the request is simply not "good business." It would seem, therefore, that it is in this attitude, this clashing

of outlook between the scientist and the business man, this lack of appreciation for each other's difficulties, that co-operation is in the first place essential. Past history has shown that the scientist need not object to the attitude of the business man, who aims at greater profits, more stability and increased efficiency. This the scientist knows will come with research. What he wants is an opportunity; and, if he is given that chance, what, on the other hand, should the industrialist expect? What, briefly, is the nature and procedure of industrial research? What field does it cover?

These questions are of real significance to this country at the present time. The relatively small amount of industrial research carried out in South Africa is limited to a few concerns, and is, in fact, of not very long duration. But there are signs throughout the country which go to show that many industries are beginning to feel the need for a more constructive policy of research. There is no doubt in my mind that a big "push" in the direction of industrial research laboratories will take place in the not too distant future. In taking this step, industries will be entering on a new phase in their struggle for bigger profits, greater stability and better services to the community. To enter this new phase in total ignorance of the nature and procedure of industrial research will, in my opinion, lead to failure, and, if this happens, it will be a long time before the industrialist will be prepared to try a second experiment. This will, of course, be as disastrous to the country as it will be to the industry itself. Overseas countries did not pass through this preliminary stage so easily, and in some cases it required a world crisis, such as the Great War, to bring the scientist and industrialist together into close co-operation. With the experience of those countries before us, there appears to be no need to stumble, provided we take the trouble to learn by their mistakes.

The Field of Industrial Research.

Industrial research deals essentially with problems which have some bearing on industry. The results of such work are first obtained in the laboratory and finally applied to the factory process. Experience has shown, however, that it is a long and thorny road from the laboratory test tube to the factory plant, since results obtained in the laboratory are not always applicable on a large scale. Economics also plays an important rôle. The field, therefore, tends to widen and the problem of directing research successfully in this field requires, in the first place, skilled knowledge and experience. Even the pure scientist himself does not always appreciate the difficulties involved and the research required in the application to industry of laboratory experiments.

An outstanding example of research carried out with a view to commercialising a laboratory experiment is found in the hydrogenation of coal. Bergius' laboratory work showed that

coal can be hydrogenated under certain conditions to produce motor oils. The large-scale application of this work was undertaken in the first place by the I.G. Farbenindustrie, and after fifteen years of experimental research, Bruckmann stated in a paper that the cost of the plant was £1,600,000 and the experimental work consumed about £2,300,000, before a certain measure of success was attained. This only included the work carried out in Germany, and not research finally carried out by the Imperial Chemical Industries or the Standard Oil Company of America.

The literature is full of similar examples, though most of them are on a smaller scale. We quote this extreme case, however, to illustrate the fact that large-scale experimental work may be a costly affair. As far as this country is concerned research of this nature would be carried out on a very small scale and with discretion. The well-equipped industrial research laboratory covers a field ranging from process control to pilot plant investigation, but there is no need to concentrate on either extreme. If industrial research is efficiently directed by men with technical knowledge and experience, there is not likely to be financial extravagance in work of this nature.

Different Types of Industrial Research.

In a broad way we might distinguish between two types of industrial research. The one aims at a satisfactory solution of a specific problem, and the other at an increase in the knowledge of the subject.

The first type of research appeals to the business instincts of most industrialists. It is the oldest and most common form of industrial research. Every industrial laboratory of any standing, apart from the ordinary control work which it carries out, is engaged on problems which require a specific solution. This kind of research is traced back to the alchemists, whose one object in the world was to transform base metals into gold. They did not succeed, but the ultimate solution of the problem of the transmutation of the metals finally came by means of the second type of research.

We should be careful not to discredit in any way the importance of research carried out on a specific problem. Its value to South African industries would be incalculable within a very short period. The difficulty, however, of this type of research is that industrialists without a technical training—and there are many in South Africa—often fail to recognise the problems of their own industry. It is a case of " all's well that ends well." If there is a profitable sale for their products, all must be well. This attitude, to say the least, is unprogressive and does not lead to the highest efficiency. It is a " mark time " policy which no intellectual industrialist can recommend in a world which is ever moving forward.

The second type of research is much broader in its outlook, and on the whole has probably been of greater assistance in the general development of industries. The industry that adopts a policy of collecting knowledge and useful information concerning its business soon finds itself in a very powerful competitive position. It becomes in time more than an industry, almost an institution, upon which the safety and progress of the State may become very dependent. In this respect we might quote the opinion of a certain statesman, who, in addressing a group of bankers, stated that he would rather know the attitude of a concern towards research than to know its fixed assets. What a shock this must have been to the bankers!

In order to illustrate more clearly the value of research which aims at a better knowledge and understanding of the process, I wish to quote a few examples which, in my view, appear to be of special interest in the history of industrial achievement:—

(a) Louis Pasteur, during his earlier life, was called in as a consultant by many French industrialists who had encountered difficulties from time to time—such as, for instance, in the manufacture of the tartaric acids, the production of alcohol from beets, the vinegar and wine industries, the silkworm industry, etc. True to his character and scientific outlook, he disregarded the immediate problem and undertook in every case a thorough investigation of the processes involved. In the course of a relatively short period he solved the problem of the tartaric acids, re-established the wine and vinegar industries on a scientific basis, and introduced the germ theory of fermentation and disease, which finally led to the introduction of antiseptic surgery by Lister in England. The diseases in vinegar and wines were traced to similar causes, namely, living microscopic organisms or germs, which accounted for the lives of 90 per cent. of the people who underwent surgical operations. Thus, there was established a close relationship between vinegar and an ulcerated limb. Once the knowledge of the process was known, it was easy to apply this knowledge and find a remedy. At about the same time or a little later, Pasteur proceeded to England to receive scientific honours, and inspected the beer industry. Here he matched the results of his planned experiments, some of which were carried out in the snow at the top of the Alps, against years of haphazard experience, which often exists in industries of long-standing duration. What a revelation it must have been to these men to have their process explained to them by one who probably had never before entered a brewery? The history of Louis Pasteur and his work will always remain one of the classic episodes of industrial research and its achievements.

(b) Edison's inventions were mostly all inventions to order. His first electric bulb—a truly brilliant inspiration—was the result of "trial and error," a successful attempt to meet a requirement. But the research which led to the further development of the electric bulb, both in America and Germany, is an excellent example of the second type of research which we are trying to describe. Irvin Langmuir entered the laboratories of the General Electric Company in 1909, and was given a free hand to choose a subject for research. At that time it was the general opinion amongst electric lamp technologists that the higher the vacuum that could be produced, the better would be the lamp. Langmuir, therefore, decided to study the conditions that existed in a lighted lamp, and devised methods by which he could study the effect of heating wires under vacuum. His early results were of no avail, so he was given a few assistants. After a few years a considerable amount of knowledge was gained about the behaviour of tungsten filaments under heat and pressure and in the presence of gases. This work led to a complete revision of ideas, and after fifteen years—an incredibly long period this must seem to the business man—the General Electric Company was able to produce, not vacuum-filled but gas-filled bulbs with 30-40 per cent. higher efficiency. This Company has been more than compensated by adopting a broad and continuous policy of research. Furthermore, Langmuir received the Nobel Prize in Chemistry for this and other scientific work of an equally brilliant character; and what industry is there to-day that would not pay heavily for the services of a Nobel Prize winner in chemistry or physics?

(c) Coming to some of the later developments, we might quote the manufacture of synthetic rubber, or Duprene (Neoprene), of the E.I. du Pont Nemours Company—a development which resulted directly from the work of J. A. Nieuwland, of Notre Dame University, on acetylene. A more classical example, however, is the discovery of the electron, as well as subsequent research on this subject. Surely, no subject has ever received a greater amount of concentrated brilliance of mind than this, the minutest particle of matter, the electron, received from the untiring efforts of Rutherford, Thomson, Aston and co-workers at the University of Cambridge. The industrial applications of this discovery and other work along similar lines need not be repeated here. It is common knowledge, but their significance is not always appreciated. The electron and its applications to industry is the discovery of the twentieth century, as Pasteur's living organism was the outstanding discovery of the last century.

These few examples, chosen from a richly-endowed history of industrial events and inventions, illustrate only too well the value of research, which aims at a broader and deeper knowledge of the subject.

Research Policy.

In the above paragraphs we have touched very briefly on the main functions of an industrial research laboratory, namely, (a) process control, (b) research on specific problems, and (c) research of a broader and continuous kind, relating to the particular industry. The question immediately arises as to the policy which should be adopted in attempting to fulfil these functions. In a recent investigation in America into the way in which research serves industry, it was found that—

(1) 37 per cent. of the industries examined placed the major emphasis of the research programme on the discovery of new products;

(2) 26 per cent. placed major emphasis on production costs, new applications and by-products; and

(3) 37 per cent. placed major emphasis on improving quality.

In South Africa conditions are somewhat different, and from my own experience I would suggest that the major emphasis in most cases should be placed on reducing production costs, improving quality and the standardisation of the product. A reduction in the production costs would place local industries in a better competitive position *vis-à-vis* the imported article; improving the quality is a much desired and necessary factor which few industries can afford to disregard, and the standardisation of the product will assist tremendously in eliminating prejudice that may exist against the locally-made product. The policy which should be followed to attain these objects is by no means straightforward, and requires in each industry the full time attention of a technically-trained man. One of the biggest difficulties, in my opinion, with which South African industries have to contend is the fact that technical men are not used in an executive capacity. In overseas countries where secondary industries have taken the lead it has been shown consistently and conclusively that technically-trained men are the best executives in industry, and the highest efficiency is obtained by the close co-operation of business and technical men. It seems to me, therefore, that industrial research policy is more wisely directed by the executive of the industry on which the technically-trained man is adequately represented. The gold mining industry presents us with an excellent example of this type of executive.

The Financing of Research.

We know of all kinds of methods that have been used in the past for financing industrial research. Edison raised capital with a view to inventing the electric globe, about which he had

a "hunch." Alexander Bell, together with a friend, organised most successful theatrical concerts and used the proceeds to carry out research on the telephone; Goodyear carried on his research on the vulcanisation of rubber while in gaol as a common debtor. The world has undoubtedly benefited considerably from these unorthodox efforts, but nevertheless they are not to be recommended. There have been many failures in industry because incorrect methods of financing research were adopted. Research should be made a fixed charge, like interest, insurance, taxes, etc., in every industry. It is the charge for intellectual property, which, in the long run, will become one of the most important raw materials of the industry. Unless a bold policy of this nature is decided upon, it would almost be better to make no start at all, for research, like gold mining, is a long-term investment. It takes five or six years before a return on the invested capital is obtained, but the return in the long run may be equally large as that of a gold mine, and probably less speculative.

Research and South African Industries.

We now come to the question of research in relation to South African industries. To what extent should we follow the lead set by overseas countries?

Germany recognised the value of industrial research before any other country. It is to-day a very important part of the industrial structure of that country. In Great Britain the Great War seemed to have been the starting point of a general organised policy of industrial research, and the results in a very wide field of industrial activity have been most remarkable. The British are, for instance, no longer dependent on Germany for their requirements of telescopic lenses, chemicals,, dyes chemical glassware and chemical porcelain. In America there are 1,600 industrial research laboratories. During the last depression, which hit American industry more severely than most other countries, an investigation showed that 75 per cent. of these concerns had decided to increase their research activities, 15 per cent. had decided on no change, and 10 per cent. on a decrease—all this in the depths of a most severe depression. What a strong argument in favour of research these figures reveal!

We need not, in fact, go into further details. Research has become the accepted policy of all industries of standing in overseas countries. It is the trend in modern industrial thought and development, and the time has arrived for this country to make serious efforts, both financial and otherwise, to follow the example. In the past South African industries were given a start, and placed on a sound footing by favourable conditions and Government aid. They are now past this preliminary stage, and must endeavour to pave their own way in a highly competitive world. The only satisfactory way of doing this is

by means of a broad, well-organised policy of industrial research. If this is accepted the question naturally arises: How should it be done?

In other countries facilities for industrial research are not lacking. There are Government laboratories, universities, privately-endowed institutions, consulting chemists and chemical engineers, and, in addition, every industry of any significance has its own laboratory and technical men. In our country the facilities are not so good. We have two relatively small Government laboratories, one specialising in the study of fuels and the other in minerals. There are, in addition, the universities, where, rightly, pure science problems receive most attention. In a few cases research of a high order is carried out by industries, but on the whole the lack of research in South African industries constitutes a void in the social and industrial atmosphere of the country which, if persisted in, will eventually develop serious consequences. It is essential for industrialists to recognise the value and importance of research, and to agree to a sound and continuous policy of carrying out such work. This can, of course, be done by the establishment of private laboratories attached to the factory or by the combination of groups of industries for the establishment of one large laboratory for research directed along broad lines, so as to obtain a more fundamental knowledge of the industrial processes. The engineering industry, for example, would, I feel sure, benefit considerably from such a scheme. Naturally, there would be practical difficulties to overcome before it could be successful—difficulties based largely on the limitations of the human mind to share the benefits of such work with competitors. But similar schemes are in successful operation in other countries, and I can see no logical reasons why industrialists should not, in the matter of research, co-operate with one another as well as with the scientifiic men who are to direct the policy and carry out the work. Co-operation with the universities is also desirable, and has, in fact, already led to most useful results in connection with a few industries. Finally, when the time arrives that industrial research is estabished as a recognised policy of private industry, the Government would no doubt consider methods by which assistance in research matters can be given to industries along lines which are to-day in operation in other countries. At the present time Government assistance takes the form of research grants and scholarships, but without the active co-operation of industries it is doubtful that anything more than a limited benefit will ever be derived from intermittent bits of research, no matter how brilliant in character. It is more particularly a broad and continuous policy of research, carried out by industry itself in co-operation with existing institutions and with Government aid, that is required, and it is hoped that this condition will soon be fully established throughout the entire industrial life of South Africa.

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PHYTOPHTHORA WILT IN CARNATION PLANTS

BY

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With 3 Text Figures.

Read 5 July, 1937.

Introduction.

In recent years carnation growing in the Transvaal has been seriously endangered by diseases termed " wilt," " stem rot," and " vrot-pootjie " (root rot). The term " wilt " is a general one, applied irrespective of the causal agent or its seat of development. " Stem rot " indicates a blackening and rotting of the base of the stem, usually affecting all tissues in the first internode, whereas " vrot-pootjie " or " root rot " is concerned with the roots.

In reviewing the literature, it appeared that " crown rot " was described by Van der Byl (1915) in carnation plants found in Natal. He attributed the disease to a *Fusarium* sp. Small (1920), Dowson (1929), White (1929), Weston (1931), Pape (1931 and 1936), and Wickens (1935) all reported on " stem rot " in carnations, describing the causal agents as *Fusarium* sp., viz., *F. culmorum*, *F. dianthi*, *F. aveneacum*, *F. sporotrichioides*. In 1924 Müller-Thurgau and Osterwalder reported on a carnation disease in Switzerland caused by *Phytophthora omnivora*, which attacked the stem at soil level. Haig (1931) reported a similar disease in Ceylon, and isolated a species of *Phytophthora*. Weston (1935), in the States, differentiated between a " wet stem rot," caused by a *Rhizoctonia* sp. and a " root rot." The " root rot " he described as affecting the roots and base of the plants, causing the foliage to take on a pale colour, followed by complete collapse in warm weather. In winter these plants may have appeared perfectly normal. Weston did not mention any causal agent. The symptoms described, however, have much in common with those of the present investigation. Mes (1934) proved *Phytophthora cactorum* to be the causal organism of a quick wilt in antirrhinums which occurs commonly in Pretoria gardens. No record of *Pythiaceae* attacking carnations in South Africa has as yet been found.

The following account is that of an investigation into the cause and development of a " wilt " in carnations which has been prevalent for the last two seasons in Pretoria.

Symptoms of the Disease.

The disease is most in evidence during the months of November, December, January and February, when the general average temperature is higher than at any other time of the year, usually accompanied by high humidity, as these months coincide with the rainy season of the Transvaal. At this time, one-, two- and three-year-old carnation plants are attacked as well as seedlings. A characteristic symptom of the disease is

Fig. 1.—Characteristic Symptoms. On left: of root rot. On right: of stem rot.

the quick and complete wilting of the plant within 24-48 hours. The leaves roll slightly inwards towards the mid-rib, and turn straight towards the stem. Their colour turns to a light greenish grey. When the plant which has just wilted is dug up, the root system comes out with deteriorated lateral roots—of which the epidermal layer has broken away, and often just a short bit is left on the main roots. The whole structure has a short, hairy and irregular appearance. On closer examination the tissues of the crown of the root and of the stem-base are seen to have a brown water-soaked appearance. If the plant is left in the soil a few days longer, and then pulled up, it easily breaks off at this point.

There is a distinct difference between this wilt and that which is termed " stem-rot " in South Africa. In the latter all the tissues in the stem base, and usually of the whole of the first internode completely deteriorate and turn black, so that the stem is liable to collapse at this point. Wilting, however, is just as quick as in the first case, and differs in this respect from the " stem rot " as described in England. (See Fig. 1.)

Isolation of the Pathogen.

In the seasons 1935-1936 and 1936-1937 diseased carnation plants were collected from gardens in the Pretoria suburbs—all of which had been established for several years and continually cultivated. In addition, plants were obtained from White River, Nelspruit, Rivonia (Johannesburg), and Kroonstad nurseries.

Microscopical examination revealed the presence of a mycelium in the tissues of the crown region of the root. When examined in the early stages of the wilting, the mycelium usually appeared non-septate and abundant, with the hyphae becoming fewer and more difficult to find higher up the stem. There, oogonia were sometimes found in the xylem vessels. In slightly later stages of the wilting, septate mycelium was also present. When diseased pieces of tissue were laid out in tap water, numerous papillate sporangia were formed within 24 hours—thereby indicating the presence of a species of *Phytophthora.*

The septate mycelium usually proved to be a *Fusarium* sp., and in one case a *Rhizoctonia* sp. was isolated.

Simultaneously other wilted garden flowers were examined, and *Phytophthora* sp. and *Fusarium* sp. were isolated from *Centaurea* (sweet sultan) and *Verbena*. Papillate sporangia were obtained from the tissues (in water) of wilted *Gypsophyllum* and *Phytophthora* oogania were found in sections of the layering stem of a wilted plant of *Scabiosa*. In the last two cases no further isolations were made. In all the plants examined, from which a species of *Phytophthora* was isolated, the typically deteriorated root system was present.

From the above it might be concluded that several species of fungi could be present in the tissues of wilted carnations.

The question now arose in how far each of them is responsible for the disease of the plant—which one primarily caused the infection and which entered only as a secondary invasion?

The fungi were separated and isolated by the following methods. The diseased section of the plant was washed in formalin (a 4 per cent. solution of commercial formaldehyde) for two to three minutes, until all soil and debris were removed, and then rinsed in sterile water. The stem was cut with a sterile knife, and the xylem in which the water-soaked area was clearly marked, exposed. Small cuts were then made from the edge of this area, which marks the line of infection and presumably the most virulent growth of the fungus. Each of these cuts was plated on oatmeal agar, and incubated for 24-48 hours at 27° C. From very recent infections a pure culture of *Phytophthora* was fairly readily obtained, if the cuts were made with extra care from the extreme edge of the infected area. Such cultures can be brought to considerable vigour by frequently transferring them to new plates, occasionally alternating the media from oat to maize agar. The importance should here be emphasised, of an early transference of the fungus, after its development on the plate—i.e., when the developing hyphae become just clearly visible on the media.

If this precaution is not observed, *Fusarium* spp., which apparently closely follow a *Phytophthora* infection, may grow out and obliterate the *Phytophthora.* Continued culturing from such a plate will give pure cultures of *Fusarium* sp. only, which is not really the causal agent of the disease investigated. We know of several cases of diseases which were first attributed to *Fusarium* sp. have later been shown to be caused by other organisms, *Phytophthora* sp. in particular. It is, therefore, strongly recommended, that in diagnosing the cause of wilts in plants, small cuts from infected tissues should be laid out in water, as well as on media plates. The presence of *Phytophthora* will soon be indicated by developing sporangia, and particular care should be taken in isolating it on media. The same difficulty was encountered when *Rhizoctonia* mycelium was present in the tissues together with that of *Phytophthora.*

Eventually pure cultures of *Phytophthora*, *Fusarium* and *Rhizoctonia* were obtained.

Several isolations were made from fresh carnation material obtained from the different sources mentioned. In each case a species of *Phythophthora* was isolated in pure culture, the strains being termed C I, C II, C III, and C IV, respectively.

C I=from full grown plant in full bloom, 13 months old.

C II=the same, but plants only nine months old.

C III=from seedlings bought from a nursery.

C IV=from plant commencing to flower.

By the same methods species of *Phytophthora* were cultured from verbena, sweet sultan and antirrhinum plants, which for convenience were termed:—

Verb.=from tall and flowering verbena plant.

SS.=sweet sultan plant forming buds.

P.c.=*Phytophthora cactorum*, as isolated from antirrhinum by Mes (1934).

The culture of *Fusarium*, isolated from full-grown carnation plants in Pretoria, and that of *Rhizoctonia* isolated from carnation plants from Rivonia and Nelspruit, were also continued, and will be referred to as *Fus.*, and *Rhiz.*

Inoculation Experiments.

Soil-inoculation and cross-inoculation experiments were carried out as follows:—

1. The six strains of *Phytophthora* were tested on carnation, sweet sultan and verbena plants, the strains being C I, C II, C III, Verb., SS., P.c.
2. The effect of seven different species of *Fusarium* as soil inoculum was tested in the winter and the summer, the cold and dry, and the hot and moist seasons respectively:—

   The seven species were obtained from the "Centraal Bureau voor Schimmel Culturen," Baarn, all of which have at some time been described in relation to carnation "wilt." They will be referred to as:—

   F.1=*Fusarium scirpi*, Lamb et Fautr.

   F.2=*F. sporotrichioides*, Sherb.

   F.3=*Gibberella acuminata*, Wr.

   F.4=*Fusarium oxysporum*, Schlecht.

   F.5=*F. culmorum*, Sacc.

   F.6=*F. avenaceum* (Fr.), Sacc.

   F.7=*F. dianthi*, P. et D.
3. The effect of *Rhizoctonia* in wound and soil inoculations was tested with the species isolated from the plants obtained from Nelspruit.

For this work, in all plantings, sterile soil was used. Special soil suitable for carnation culture was obtained from a local nursery, and just before use sterilized in the autoclav for one hour at 15 lbs.

The seed was obtained from Messrs. Starke's, in large enough quantity to supply the necessary plants for the whole investigation. Carnation seed was of the "New Giant-Flowered Malmaison Strain"; sweet sultan and verbena were of the "Choice Mixed" variety. Indoor-experiment-plants were grown in 9in. pots, whereas for the outdoor experiments cocoa-tins were used. The latter proved especially useful in preventing the soil and roots from drying out. During the winter months the experi-

ments were carried out under cover, i.e., in the greenhouse, and in an open pothouse, but from early spring (October), all plants were moved into the open, and thus exposed to rain and sunshine. All carnation plants were left to develop naturally—no stopping or disbudding was practised. The blooms, however, were regularly removed later. Seed was sown in January, August and December, 1936, supplying the plants of different age for the experiments described below.

Inoculations with the different fungi into the soil were made by carefully lifting the soil with a spoon, $\pm$ 2 inches away from the stem, and placing the inoculum into the hole, which was then again covered up. The inoculum consisted of a small block of media with mycelium often carrying sporangia. Unless specially mentioned none of the plants was wounded. In all experiments, wilted plants were examined for the cause of death. In all *Phytophthora* inoculations the presence of the fungus was proved either in water or reisolated on media, as stated in the experiments concerned.

A—With Phytophthora Species.

Experiment 1:

On 6th May, 1936, the strains C I, C II and C III were inoculated into the soil in which plants two months old and $\pm$ 3 inches in height were established in the greenhouse. Four plants were inoculated with each strain, and an extra four were kept as controls. After two weeks one of the C II plants died, and *Phytophthora* was isolated from it. A plant of the same age was replanted. From then until the 15th March, 1937, the results may be tabulated as follows:—

Table 1.—Results of Winter Inoculations with C I, C II, and C III.

Species.	Date of Infection.	Number of Plants.	Total Number of Plants dead after months: 5	6	8
C I ...	6/5/1936	4	0	2	3
C II ...	6/5/1936	4	1	3	4
C III ...	6/5/1936	4	0	0	0
Control ...	6/5/1936	4	0	0	0

Experiment 2:

On the same date as the above, three plants inoculated with C I, and three control plants were put out in the open pothouse. The three plants wilted after six, seven and eight months respectively. In both experiments the plants developed normally through the winter months to the flowering stage, apparently unaffected by the fungus. On closer examination, however, a small difference in general vigour between inoculated and control plants could be observed. In October and November, with increasing temperatures, "wilt" developed, from which it may be concluded that the development of the fungus, and thereby

the wilting of plants, are dependent on higher temperatures. This agrees with the observations made by other investigators of wilt in garden plants.

Experiment 3:

Thirteen plants obtained from Krohn's nursery in March, 1936, transplanted into sterile soil, developed normally and flowered profusely. On 10th December, i.e., after nine months of growth, seven pots were soil inoculated with C I, the remaining six were used as controls. After six weeks five plants had wilted from a *Phytophthora* infestation. All pots were replanted with seedlings, which became well established, especially due to cool days, but wilted suddenly after ten days. There was, therefore, a considerable difference between the rate of wilting in old and young plants. This phenomenon, and similar ones in Exps. 4 and 7, may be explained on the basis that the old plants were established in sterile soil, and then only was the inoculation made. The fungus, therefore, had to develop in the soil first, and then penetrate the plant. The carnation seedlings, however, were planted in heavily infested soils, and infection naturally followed much sooner.

Experiment 4:

On 3rd April, 1936, 24 plants of sweet sultan, $\pm$ 6 inches in height with three whorls of leaves well formed, were treated as follows:—

The strains C I, Verb. and P.c. were inoculated each into three pots; nine pots were infected with SS., and six plants were kept as controls.

The results were tabulated as follows:—

TABLE 2.—Results of Inoculations of C I., Verb., SS., and P.c., on Sweet Sultan Plants.

Species.	Number of Plants.	Total Number of Dead Plants after months: 5	6	8
C I	3 ...	0	1	3
Verb.	3 ...	2	3	3
SS.	9 ...	0	4	9
P.c.	3 ...	1	1	3
Control	6 ...	0	0	0

After eight months all controls were in full bloom. The sweet sultan plant is apparently sensitive to all the different isolations of *Phytophthora* inoculated. Here, too, as in the above carnations, the plants remained apparently healthy during the winter months. The first symptoms of disease occurred in September, the commencement of summer. On 31st December, 1936, all sweet sultan control plants were cleared and the pots, together with those containing *Phytophthora* strains, were replanted with carnation seedlings—three weeks old.

The results were as follows:—

TABLE 3.—Effect of Infested Soils on Carnation Seedlings.

Species.	Number of Plants.	Total Number of Plants Dead after days: 4	5	9	12	15	19	20
C I ...	3	0	2	0	3	3	3	3
Verb. ...	3	0	0	1	1	2	2	3
SS.	7	3	3	4	4	5	6	7
P.c. ...	3	0	0	0	0	0	0	0
Control ...	6	0	0	0	0	0	0	0

After three weeks all controls flourished. C I, Verb. and SS. were again isolated from the wilted carnation seedlings. The relative sporangia measurements of these are shown below. The rapid wilting of the seedlings in infested soils may be explained as in Exp. 3. The reason why P.c. failed to cause infection is not so evident, because in Exps. 7 and 8, it proved to be capable of causing wilt. Possibly the culture died out suddenly, as also happened in plate cultures.

Experiment 5:

On 3rd March, 1936, three pots containing five seedlings each of sweet sultan were inoculated with the strain C III. Three similar pots without inoculum were kept as controls. All seedlings were 1½ inch in height. After six months all plants were still flourishing, but a distinct difference in size of plants, between inoculated and control pots, was evident. In the control plants the outside seedlings had developed three distinct whorls of leaves, whereas the C III showed one-two whorls, and the leaf blades smaller. There was, however, no sign of wilt. This difference remained until the end of December, when all plants died off naturally. The average flowering stem in the controls was 16-18 inches in length, flowering profusely, whereas those of the C III group were only 10 inches, bearing few blooms. Apparently the presence of the C III in the soil retarded the natural growth of the plant.

A similar effect of the C I strain was found when comparing three plants inoculated on 6th May, 1936, with three control plants of the same age (three months at inoculation). After three months, a distinct difference in the two groups showed in the development of plant size, and after four months, a considerable difference in the flowering stems revealed itself:—

1.—Size of Plant.

Inoculation.	1st Plant.	2nd Plant.	3rd Plant.
C I	7 inch	12 inch	14 inch
Control	17 inch	17 inch	17 inch

2.—Buds and Flowering Stems.

Inoculation.	1st Plant.	2nd Plant.	3rd Plant.
C I	—	One stem and 4 buds	—
Control	Many stems 5-7 buds p. stem	Many stems 5-10 buds p. stem	Many stems 7-12 buds p. stem
	Plants generally sturdy, buds well developed, blooms, bigger, and leaves more fleshy.		

After six months the difference still existed when the C I plants wilted.

Experiment 6:

On 28th November, 1936, when high temperatures (up to 94° F.) and rainy weather alternated, 130 tins with carnation plants, four months old, were set up in the open in rows of five. Two rows of five were retained as controls, and the remainder were submitted to a series of inoculations. On 10th December, 1936, the strains C I, C II, C III, Verb., SS., and P.c. were soil inoculated each into five tins.

The results on the carnation plants are tabulated as follows. The dates of planting and of inoculation are indicated, and further, the time of wilting of each individual plant is marked, so as to clearly show the rate of wilting in each strain.

Table 4.—Results of Summer Inoculations of C I, C II, C III, Verb., SS., and P.c. on Carnation Plants.

Date.		Control.	C I.	C II.	C III.	Verb.	SS.	P.c.
28 November	...	10	5	5	5	5	5	5
10 December	...	—	inoc.	inoc.	inoc.	inoc.	inoc.	inoc.
14 December	...	—	—	—	—	1	—	—
20 December	...	—	—	—	—	—	2	—
22 December	...	—	1	—	—	—	1	—
23 December	...	—	2	—	—	—	—	—
26 December	...	—	2	1	—	—	1	—
4 January	...	—	—	—	—	—	—	1
9 January	...	—	—	—	—	—	—	1
12 January	...	—	—	1	—	—	—	—
20 January	...	—	—	1	—	—	—	1
21 January	...	—	—	1	1	—	—	—
9 February	...	—	—	—	1	—	—	—
26 February	...	—	—	—	1	—	—	—
15 March	...	—	—	—	—	1	—	—
Total wilted	...	0	5	4	3	2	4	3

Immediately on the death of a plant, the tins were replanted with carnation seedlings, three weeks old. All of these died within three weeks after planting, and when laid out in tap water sporangia formation proved the presence of a species of *Phytophthora.*

Carnation plants are apparently sensitive to all the *Phytophthora* isolations inoculated. The time which expires between inoculation and the first symptom of wilt, differs in the strains of *Phytophthora*, but also in the different experiments, for which there may be several causes. Firstly, the fungus must, when brought into the soil, establish itself. The rate at which this is accomplished may vary in the individual pots, with the different strains of *Phytophthora* and in the various experiments. The importance of this factor was clearly brought out in Exps. 3 and 4, and again in this experiment, by the fact that all carnation seedlings planted in infected soils wilted within three weeks. Secondly, some plants may have been weaker than others, and so offered less resistance to the fungus. Thirdly, there is the possibility of some strains being more virulent than others.

From the above experiments it may be suggested that carnations are least susceptible to P.c., Verb. and C III, whereas the C I and SS. strains are particularly virulent.

B—With Rhizoctonia Species.

On 18th February, 1937, *Rhizoctonia* sp., isolated from carnation plants received from Nelspruit was inoculated into plants $5\frac{1}{2}$ months old (as in Exp. 8) in the following way:—

I. Five plants were wounded at soil level and *Rhizoctonia* inoculated into the soil.

II. Five plants were wounded at soil level, and the stem then packed around with soil, covering the first internode, after which the soil was inoculated with "Rhiz."

III. Five plants were soil inoculated, but not wounded.

IV. Five plants were soil inoculated, and well packed, but not wounded.

The object was to show the effect of *Rhizoctonia* in the soil upon wounded and non-wounded plants, and further, what difference deep planting made to the attack of the disease. On 10th March, 1937, wilt showed as follows:—

I, III and IV showed no infection.

II: Three plants wilted from stem rot.

At the time of writing the plants are still under observation—and there is still a possibility of more plants wilting.

The results so far corroborate the statements by Peltier (1919) and Weston (1931), that *Rhizoctonia* causes a stem rot only, and that it is primarily a wound parasite which is particularly virulent when the plants have been planted too deeply.

C—With Fusarium Species.

Experiment 1:

The seven species of *Fusarium* were soil inoculated towards the end of July, 1936, each into six small pots containing seed-

ling carnation plants—2-3 inches high. Six similar plants were used as controls. The plants were left in the greenhouse till the 20th November, when none of them showed any sign of wilt. The plants were then discarded as the pots were becoming too small for the normal development of the plant.

Experiment 2:

On the 26th November, 1936, this experiment was again repeated on the plants grown in tins outside the greenhouse. F 1-7 were inoculated into five tins each, and 10 plants were used as controls. By the 15th March, 1937, no plants had died of wilt. Wound inoculations were then made into the stem bases of the plants with the respective species of *Fusarium*. For the effect of these the plants are still kept under observation.

D—Conclusions from Experiments.

1. All strains of *Phytophthora* isolated are pathogenic to carnation plants 12 months, 9 months, 4-6 months, and 4 weeks of age.

2. The rate of infection of plants already established in sterile soil may differ in the various strains of *Phytophthora* and under different conditions. High temperatures and humidity seem to be most favourable to the incidence of disease.

3. Carnation seedlings planted in soils already infected with the various strains of *Phytophthora* all wilt within three weeks, under conditions of high temperatures and humidity.

4. C I, Verb. and SS. strains are pathogenic to sweet sultan as well as to carnation plants.

5. C III strain is apparently pathogenic to sweet sultan.

6. *Rhizoctonia* enters the plant through the base of the stem, and does not primarily cause a root rot. Wounding and deep planting are apparently the main factors in the incidence of the disease.

7. *Fusarium* sp. 1-7 do not enter the plant, through uninjured roots, as a primary infection, because four months after inoculation no sign of wilt is evident.

The Pathogen.

The pathogenic virulence of C I, C II, C III, C IV, Verb., SS., and P.c. was tested on grapefruit, apples, tomatoes, and potatoes. In all cases the pathogenicity of the isolates to the different hosts was fairly uniform. Green tomatoes rotted in four days from wound inoculations, potatoes softened after seven days, whereas on grapefruit they were equally virulent. The development of the infection in apples was much slower, though comparatively the same in each strain, except in C III. In the latter no development of the fungus was obtained.

The seven strains were also submitted to a series of temperature tests with special reference to mycelial growth. From these tests it appeared that the optimum temperature in relation to growth for all isolates generally ranged between 30°C. and 32°C. Sometimes a second optimum showed at 25°C. C III proved a very vigorous grower, and though within 24 hours a difference was indicated with an optimum at 32°C., after 48 hours all plates in all cases were still showing growth at 35°C., whereas the maximum for the other strains was 33°C.

A—*Morphology.*

The seven isolates of *Phytophthora* were cultured on several standard media, such as oatmeal agar, maize-meal agar, steamed maize, prune agar, lima-bean agar, and potato-dextrose agar. All of them produce an abundant white aerial mycelium at room temperature, on oat and maize agar, growing luxuriantly and completely filling the petri-dishes. The mycelium is non-septate, and at first inclined to be smooth and globulose. Later this becomes nodulose and irregular, and after two weeks sporangia in most cases are abundant on both types of media. On steamed maize-meal, a cottony mass of mycelium develops in which sporangia are usually produced in moderate numbers after two weeks. On prune agar, lima-bean agar and potato-dextrose agar, the fungus produced a delicate, moderately dense mycelium with scant aerial growth, but inclined to spread into the media. irregular and knobby.

When all strains were reisolated from the tomatoes into which they had been inoculated, the mycelium was in all cases rugose and very irregular. In the isolations from the apples, the mycelium was smoother. On the whole it seems as if irregular and knobby growth is associated with a more acid reaction of the media.

C III differs in all respects from the other six isolates—in pathogenicity, in temperature reaction and in cultural growth. It develops a profuse white and dense mycelium in all types of media, covering the plate completely in 48 hours. Sporangia were never found in culture, but oogonia were always abundant on maize and crushed-oat media.

All strains except C III very easily produce sporangia in maize and oat agar, as well as in tap water and petri solution. The typical sporangia are papillate, ovate and vary in size with the isolate, with the media, and the age of the culture. The papilla is usually definite, hyaline and apical, whereas in some cases it may be indistinct, or on the other hand extremely elongated, as was found on tomato in water, or in petri.

In C II abnormal sporangial forms were found. Large lobe-like structures developed at the end of a hypha. In appearance these resembled overgrown sporangia, sometimes branched with the walls irregularly thickened. Apically, or laterally, hyphae

grew out on which normal sporangia were again formed. (See Fig. 2.) In water and in petri solution swarm spores were readily formed. The zoo spores became active in the sporangium. They may be liberated singly or in a mass, but without any evidence of a vesicle. They swarmed around for a while, came to rest and germinated. Swarm spores left behind in the sporangium were found to do the same. The number of swarm spores may vary from 10-30 and more, and are 7·7 μ in diameter In some cases, the sporangium germinated directly by means of a germ tube at the end of which occasionally another sporangium was produced. On oat agar, the sporangia may germinate with a germ tube, or the contents gradually ooze out, apparently degenerated. In old cultures sporangia were also found in which the contents had contracted to a ball.

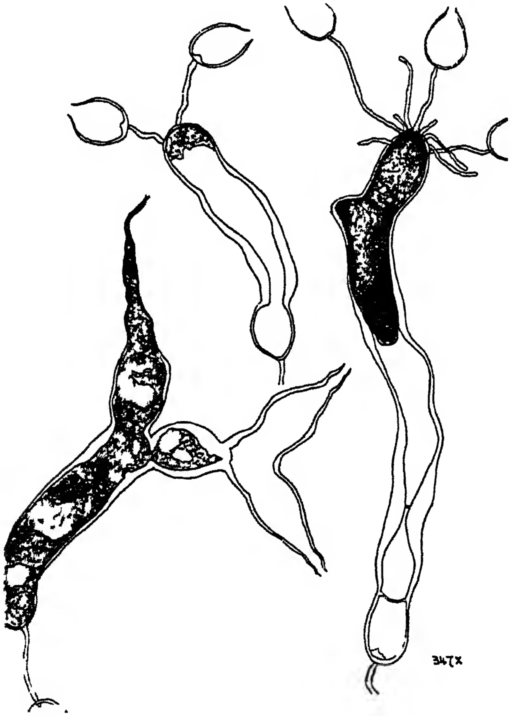

Fig. 2.—CII Strain: Abnormal sporangial forms.

C III differed from the others, in that it immediately produced oogonia, and that no sporangia were found in culture. Mehrlich's (1935) method was applied to stimulate sporangia formation. The mycelium was grown on malt broth for four days at 25°C., then washed in sterile water, and incubated at

25°C in non-sterile soil-leachate No sporangia were produced Twice, however, the sporangia were found just after reisolation Firstly, C III was reisolated from wilted carnation plants into which it had been inoculated When bits of infected tissue were laid out on oat agar, sporangia formed On placing a tuft of mycelium in petri solution, swarm spores were liberated, or the sporangium germinated by means of a germ tube (See Fig 3) A little later, however, only oogonia were produced

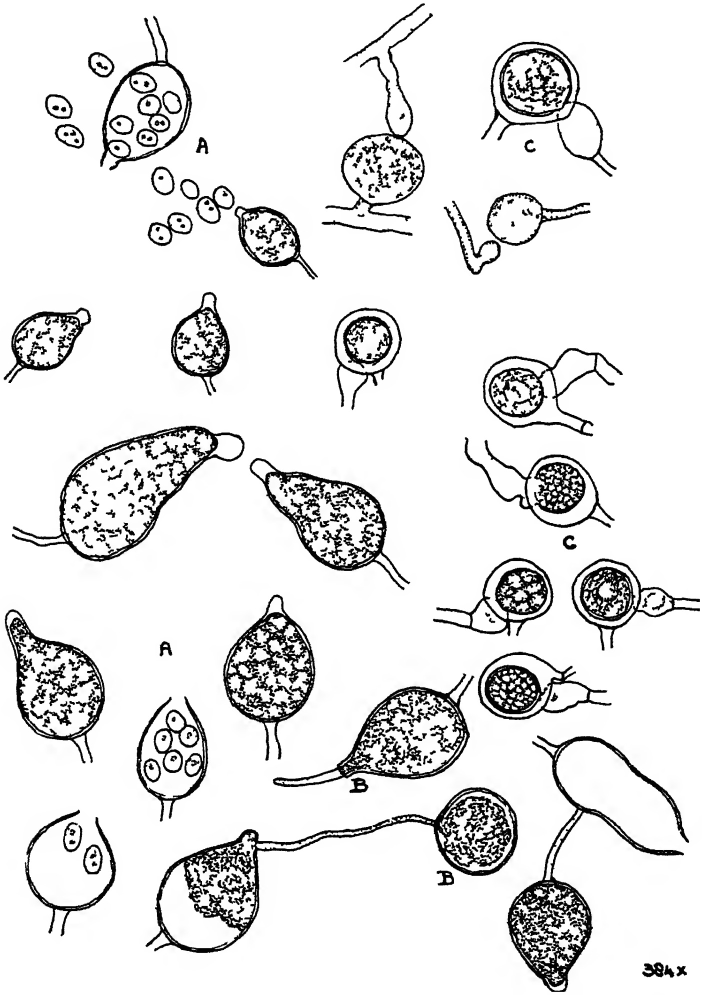

Fig. 3—CIII Strain· A. Sporangia in petri-solution; B. germinating, C. oogonia.

Secondly, when a small piece of tomato infected with C III was laid out in petri solution, sporangia with swarm spores were produced after 40 hours. These sporangia were exceptional in that they varied so widely in size, that the smallest and largest sporangia ever observed were found amongst them. Three hours later, however, only a few evacuated sporangia were left, and oogonia were rapidly being formed. (See Fig. 3.) The production of oogonia on tomato in petri solution was not observed in any of the other isolates. This very short period of sporangia formation may explain why sporangia were not found earlier in the study of C III.

Measurements were taken of sporangia formed in water, petri solution, and on oat agar. In each case 50 sporangia were measured. Average and extreme dimensions are given in the following table. The oat agar cultures used were two weeks old.

TABLE 5.—Average and Extreme Dimensions of Sporangia from isolates on different media.

Species.	Media.	Average (in micra).	Extremes (in micra).
C I ...	Oat-agar ...	37·3 × 30·3	49-26 × 37-22
C II ...	,, ,, ...	34·5 × 27·6	49-26 × 39-26
C III ...	,, ,, ...	40·9 × 32·4	49-26 × 37-22
C IV ...	,, ,, ...	39·6 × 30·9	45-28 × 37-22
Verb. ...	,, ,, ...	34 × 27·4	45-26 × 35-20
SS. ...	,, ,, ...	43·4 × 35·9	51-30 × 45-28
P.c. ...	,, ,, ...	33·1 × 26·8	35-24 × 27-24
C I ...	in water ...	30·4 × 23·3	39-22 × 27-18
C II ...	,, ,, ...	42·8 × 34·2	51-32 × 41-28
C III ...	petri sol. ...	37·2 × 27·9	57-12 × 41-16
Verb. ...	in water ...	34·5 × 28·2	49-28 × 41-22
SS. ...	,, ,, ...	35·8 × 26·5	49-26 × 35-18
P.c. ...	,, ,, ...	31·1 × 25·3	35-24 × 27-22

Apparently there exists a considerable variation in the size of sporangia, even within each isolate. On oat agar, e.g., the SS. produces the largest sporangia, whereas in water SS. is only third in size. C II is largest again in water, but comes fifth on the oat media.

The occurrence of sexual reproductive organs in the different isolates varies even more. C III and P.c. produced numerous oogonia, the latter especially on maize agar. In the case of C I oogonia were only once found (on 31st December, 1936) in the tissues of an inoculated plant. On the same day SS. produced numerous oogonia on oat media—of both measurements were made. In neither have oogonia been since recorded. A possible explanation may be that here the formation of oogania coincided with excessive heat and humidity, the temperatures in that week running up to 94°F. From C II only a few oogania were found

in an oat culture six months old—whereas after eleven months they appeared to be fairly numerous. In Verb. no oogania have as yet been found.

When oogonia were found they were smooth, spherical or sub-spherical, sometimes with a broad funnel-shaped base. The oospores were spherical, light yellow and surrounded by a thick wall. Of particular importance is the fact that in all cases noted, i.e., C I, C II, C III, SS., and P.c., the antheridia were paragynous. One and sometimes two antheridia were found on one oogonia. The average measurements of oogonia obtained from the isolates can be tabulated as follows:—

TABLE 6.—Average and Extreme Diameters of Oogonia from the Isolates.

Species.		Host.		Average (in micra).	Extremes (in micra).
C I	...	Wood tissue	...	25·3	32·2-23
C II	...	Oat agar.	...	23	25·3-21
C III	...	,, ,,	...	20·7	29·9-18·7
Verb.	...	—	...	—	—
SS.	...	Oat agar.	...	24·3	29·9-20·7
P.c.		,, ,,	...	23·5	25·3-20·7

Chlamydospores have been found in C I, C II, Verb., SS., and P.c. They were spherical, thin walled and light yellow in colour. The following table shows the average and extreme diameters of the chlamydospores which were found on oat and maize agar.

TABLE 7.—Average and Extreme Diameters of Chalamydospores.

Species.		Number Measured.		Average (in micra).		Extremes (in micra).
C I	...	8	...	28·65	...	33 × 28
C II	...	15	...	32·51	...	34 × 20
Verb.	...	10	...	30·36	...	36 × 24
SS.	...	9	...	28·75	...	33 × 26
P.c.	...	2	...	23	...	—

The average diameter of the chlamydospores varies from 23-32·5 μ, and in none of the cultures were produced in very great abundance. In old cultures from C II and Verb. they were the most numerous, whereas none were found in C III. Occasionally, in cultures from Verb., the chlamydospores were surrounded by outgrowths from neighbouring hyphae, resembling antheridia in their shape and dense protoplasmic contents.

B—*Identification.*

In the isolates C I, C II, C III, Verb., SS., and P.c. an irregular mycelium, non-septate, was found. Sporangia were

produced in abundance from which swarmspores were discharged, complete and without the formation of a vesicle. Oogonia and antheridia were present at some time or other in all isolates, except in Verb. On the presence of the latter, and of the typical sporangia, the isolates were classified in the genus *Phytophthora*.

Tucker's (1931) system of classification was further applied in identifying the species of the isolates. Tucker in the first instance divides his species on the basis of the paragynous and amphigynous antheridia. Only two species belong to the former group, viz., *P. cactorum* and *P. syringae*. As paragynous antheridia were found in all isolates in which oogonia were produced, these should therefore be classified as either *P. cactorum* or *P. syringae*. *P. syringae* fails to grow at temperatures above 25°C., whereas the isolates have an optimum temperature of 30°-32°C. It also differs from the isolates in the production of non-papillate sporangia. According to Tucker, therefore, the isolates can be identified as *Phytophthora cactorum* (L. and C.).

The absence of oogonia in Verb. renders its identification more difficult. There are, however, thin walled chlamydospores present, similar to those in the other isolates. According to Tucker in *P. cactorum*: "The chlamydospores are very similar in appearance to unfertilized oogonia, and it is possible, perhaps probable, that the bodies here considered chlamydospores are oogonia which failed to come into contact with antheridia, or failed to become fertilized from other causes." The presence of antheridial-like growths surrounding some of the chlamydospores may support this view. For this reason Verb. may possibly fall within the *P. cactorum* group. Further, the isolates agree with *P. cactorum* in the growth on different media, the presence of papillate sporangia and thin walled chlamydospores, and in pathogenicity. All isolates were severely pathogenic to tomatoes, and attacked potato tubers and grapefruit. The infections in apples developed much slower, though comparatively the same with all isolates, except C III. The latter proved a very weak pathogen on apples. In the individual isolates, however, variations from *P. cactorum* species as described by Tucker, are met with. The following characters are of importance:—

(a) Size and Production of Sporangia.—The results of measurements made of sporangia in the isolates, cultured under different conditions, showed a wide variation. Tucker gives as average dimensions found in *P. cactorum* 30·3 x 22·9 μ. The dimensions obtained in sporangia from the isolates vary from these, even within the same isolate. (See Table 5.) Variability in the size of sporangia is known to occur in species of *Phytophthora*. According to Tucker (1931): "Considerable variation in sporangium size occurs within each species. . . . . The dimensions of sporangia considered independently of other characters cannot be accorded much importance taxonomically.

In connection with other characters, however, their morphology becomes of some value."

The production of sporangia in the isolates was abundant on most media except in C III. Oogonia were here produced immediately, and only on two occasions were sporangia met with, namely, on reisolating the fungus from a carnation plant and from tomatoes which had been inoculated.

(b) Production of Oogonia.—Their number varied in the isolates—very numerous in C III, sporadic or rare in C I, C II and SS, absent in Verb. According to Tucker (1931), Leonian (1936) and others, sexual bodies appeared in culture sooner and more readily in the case of *P. cactorum* than in any other species of *Phytophthora*. The identification of the above isolates, as *P. cactorum*, might then appear contradictory. Leonian (1936), however, has also shown that the sexual reproduction in *P. cactorum* was controlled by certain sexuality-inducing substances. His experiments indicated " that *P. cactorum* cannot synthesise growth-promoting and sexuality-inducing substances, but must obtain them from some other source." Possibly, therefore, these substances in some of the carnation isolates were produced either very late or in insufficient quantity. Further experiments on the conditions favouring sexual reproduction will be carried out. Nevertheless, C I, C II and SS. can be identified as *P. cactorum*, because whenever oogonia were found the antheridia were of the paragynous type.

(c) Growth and Temperature Relations.—In the isolates C I, C II, C III, Verb., SS., and P.c. the optimum temperatures for growth ranged between 30°-32°C., whereas the maximum for all isolates except C III was 33°C. C III still showed growth at 35°C. These optima and maxima were slightly higher than those obtained by Tucker for *P. cactorum*. He found 25°-27°C. to be the optimum, although profuse growth still occurred at 30°-32°C. No growth showed at 35°C.

C—*Discussion.*

In summarising the above facts, the conclusion may be drawn that the five isolates C I, C II, C III, SS., and Verb. belong to the genus *Phytophthora*. Furthermore, Verb. may possibly, and the remaining four isolates definitely, be identified as belonging to the *P. cactorum* (L. and C.) group.

The following characteristics were responsible for this identification:—

1. The presence of paragynous antheridia in all isolates where oogonia were produced.
2. Production of papillate sporangia.
3. The presence of chlamydospores.
4. Growth on different hosts.
5. Pathogenicity to many hosts.

Apparently the isolates varied considerably between and even within themselves in:—

(a) Size and production of sporangia.

(b) Production of oogonia.

(c) Growth and temperature relations.

These variations might be considered by some of sufficient importance to warrant the establishment of new species. It should, however, be borne in mind that:—

1. Size and production of sporangia was known to be a variable characteristic in the case of all species of *Phytophthora*.
2. The production of oogonia may be controlled by certain growth substances whose production was again dependent upon external factors.
3. The previous history and environment may influence the temperature relations of the fungus.

Although Tucker's classification cannot be anything but artificial and has not been approved of by all research workers, in the present case his system appeared most suitable and was adopted. In this *P. cactorum* may be considered as a group within which a certain amount of variations was permissible. If all variations were utilised in describing new species, or even varieties, in a variable genus such as *Phytophthora*, nothing but taxonomic chaos could evolve.

Summary.

1. A review of the literature on carnation "Wilt" was made, and no reference to Pythiaceae attacking carnation plants in South Africa was found.

2. The terms *Fusarium* wilt, stem rot and root rot were differentiated.

3. Seven isolates of *Phytophthora* were obtained from carnation, sweet sultan, verbena and antirrhinum plants. In all cases the entry into the plant had been through the roots.

4. Inoculation and cross-inoculation experiments were made with six isolates, and it was found that all isolates were able to infect carnation plants.

5. Soil inoculations with *Rhizoctonia* caused stem rot.

6. Soil inoculations with seven species of *Fusarium* produced no wilt after six months.

7. The pathogenicity of the isolates was tested on tomatoes, potatoes, apples, and grapefruit, and all proved to be positive.

8. Growth and temperature relations were studied, and it was established that the optimum temperatures for the isolates ranged between 30°-32°C. The maximum was 33°C., and for the C III strain even above 35°C.

9. The isolates were identified as belonging to the *Phytophthora cactorum* (L. and C.) group.

The writer wishes to express her indebtedness to Dr. Margaretha G. Mes, whose advice and criticism have been invaluable.

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South African Journal of Science, *Vol. XXXIV, pp. 214-217, November, 1937.*

ATALAYA CAPENSIS: A NEW GENERIC RECORD FOR SOUTH AFRICA

BY

R. A. Dyer,

National Herbarium, Division of Plant Industry, Pretoria.

With Plate I and 2 Text Figures.

Read 5 July, 1937.

The tree *Atalaya capensis* was first discovered by Forester Dix growing " alongside of the road below Longmore Settlement," near Port Elizabeth, in the eastern Cape Province. Herbarium specimens were collected from the same tree in May of 1934 by A. D. Mitchell, District Forest Officer in that area, who forwarded them for identification to the Director of Forestry. The discovery is of such scientific interest and importance that a brief account of the steps which culminated in its description seems desirable.

When the material was submitted for naming to the National Herbarium, Pretoria, it must be admitted it was extremely difficult to believe that there existed an undescribed tree in the bush of the eastern Cape Province. The area has been botanised so thoroughly during the past 150 years, in which period Thunberg, Masson, Burchell, Ecklon, Zeyher, Drége, to mention only the more notable earlier botanists to visit the area, that it seemed incredible that all these and other keen observers should have overlooked it. Mr. A. D. Mitchell and Mr. J. J. Kotze, Chief Forest Research Officer, who also saw the tree in its native habitat, were very emphatic that it is indigenous in those parts.

The tree photographed by Mr. J. J. Kotze, with Mr. Mitchell standing under it, is the largest one discovered so far. Herbrarium specimens, F.D. 8864 (flowers) and F.D. 8933 (fruit), were collected from it.

Since the identification of the tree was uncertain, material was submitted first to the Director, Royal Botanic Gardens, Kew, and subsequently both to the Director, National Herbarium, Melbourne, and to the Government Botanist, Brisbane, Australia, to all of whom I am very grateful for assistance. I am particularly indebted to my colleague, Dr. H. G. Schweickerdt, Botanist for South Africa at Kew, for a detailed report which materially assisted me in arriving at a definite conclusion. I am indebted also to Miss C. Letty for the drawings.

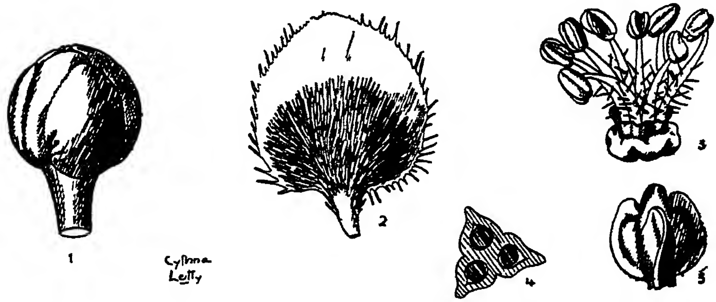
The habit, floral and fruit characters of the new tree agree in all essential details with the generic description of *Atalaya*,

[Photo by J. J. Kotze.

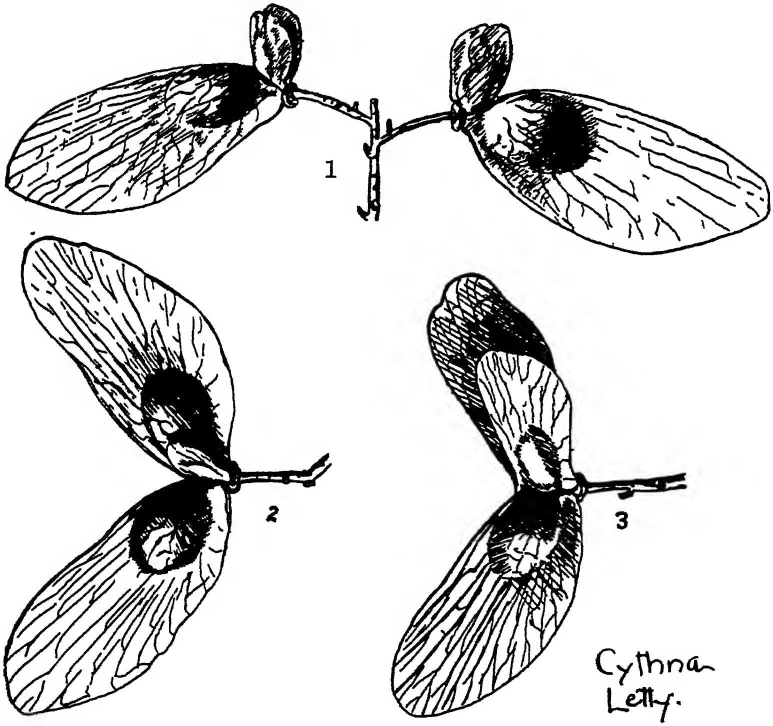
Atalaya capensis R. A. Dyer.

To face Page 214

in the family *Sapindaceae*, and it seems to fall naturally into this genus The winged fruit breaking into 1-3 samarae excludes it from any genus in this family previously recorded from the continent of Africa.



1, bud; 2, petal with appendage; 3, disc with stamens; 4, cross section with ovary; 5, ovary.



1, two fruits with one samara each developed; 2, fruit with two samarae, one aborted; 3, fruit with two perfect samarae and the third imperfectly developed.

The discovery of a new herbaceous species in South Africa is not unusual; the discovery of a new species of tree belonging to a previously recorded genus is now infrequent, but the discovery of a new species of tree in South Africa belonging to a genus previously recorded only from Australia and Timor is certainly most remarkable. It revives the controversial subject of a previous land connection between South Africa and Australia—the lost Gondwanaland—and the origin of the flora of the Southern Hemisphere.

Atalaya capensis, R. A. Dyer, sp. nov. capensis singularium. *Arbor* usque 7 m. altus. *Folia* paripinnata, rache 4-6 cm. longo; foliola 3-5- jugata, 2·5-6 cm. longa, 1-1·5 cm. lata, raro maiora, lanceolata, elliptica vel oblongo-lanceolata, integra vel perrariter lobata, apice acuta vel raro obtusa nonnunquam recurvato-mucronulata, utrinque prominente reticulato-venata. *Paniculae* foliis breviores vel longiores; rami bracteis subulatis et pilis paucis instructi vel glabri; pedicelli 3-5 mm. longi. *Sepala* 5, imbricata, circiter 3·5 mm. longa, circiter 3 mm. lata, exteriora minora, suborbiculata, intus valde concava, ciliata. *Petala* 5, sepalis interioris minora, breviter stipitata, extra basin versus dense pilosa, intra pilis paucis et squama hirsuta instructa. *Discus* carnosus, subcrateriformis, margine undulato plus minusve expanso. *Stamina* 8, intra discum inserta, petalis longiora, filamentis pilosis, antheris oblongis. *Ovarium* 3 loculare, triquetrum, glabrum; stylus usque 7 mm. longus. *Fructus* 1-3- alatus, plerumque 1-2 samaris abortivis; samarae plus minusve 3 cm. longae. intra loculo glabro usque 1 cm. longo; alae 1·25-1·5 cm. latae.

Distribution—Cape Province: Port Elizabeth Div.; alongside road below Longmore Settlement, almost opposite the large cutting in the krantz, May, 1934, Mitchell in F.H.* 8451 and in N.H. (fruit); same tree, December, 1934, Mitchell in F.H. 8586 and in N.H. (flower); January, 1936, Mitchell in F.H. 8864 and in N.H. (flower); April, 1936, Mitchell in F.H. 8933 and in N.H. (fruit); January, 1937, Forester Sims in F.H. 8979 and in N.H. (type, flowers); April, 1937, Forester Sims in F.H. 9011 and in N.H. (type fruit). Alexandria Div.; Zuurberg, January, 1937, Forester De Klerk in F.H. 8980 and in N.H.

A small *tree* up to about 7 m. high with a stem about 15 cm. in diameter (1 m. above ground); branchlets leafy and somewhat sparsely covered with lenticels, glabrous. *Leaves* paripinnate; the rhachis usually 4-6 cm. long and often produced slightly beyond the last pair of leaflets, glabrous or occasionally with a few hairs, especially near the petiolules; leaflets in 3-5 pairs,

* F.H.=Forestry Department, Herbarium; N.H.=National Herbarium, both of the Union of South Africa. The numbers 8979 and 9011 were selected as the type numbers of the flowers and fruits respectively, because duplicate material of both is available for distribution to several of the more important local and oversea herbaria.

usually opposite, shortly petiolulate or subsessile, 2·5-6 cm. long, 1-1·5 cm. broad, rarely up to 7 cm. long and 2 cm. broad, lanceolate, elliptic or oblong-lanceolate, entire, very rarely lobed, acute, rarely obtuse, often with a recurved mucronulate apex, reticulate venation fairly prominent on both surfaces, petiolules glabrous or with a few hairs. *Inflorescence* densely or sublaxly paniculate; panicles terminal or in the axils of the upper leaves, shorter or longer than the leaves; the axis and its branches glabrous or thinly pubescent, bracteate; the bracts small, subulate, pilose often glabrescent; pedicels 3-5 mm. long, slender. *Sepals* 5, imbricate, about 3·5 mm. long and 3 mm. broad, the outer ones smaller, suborbicular, the inner face concave, ciliate. Petals slightly smaller than the inner calyx lobes, shortly stipitate, pilose on the back more densely so towards the base, sparsely pilose on the inner face and furnished with a hirsute appendage from above the stipe, ciliate more densely so and with longer hairs towards the base. *Disc* fleshy, expanded at the base and slightly notched opposite the petals, upper margin undulate and expanded with age. *Stamens* 8, filaments inserted within the disc, sparsely pilose; anthers oblong, divided at the base. *Ovary* three-celled, apparently often aborted, at least those in the first opened flowers; carpels with one ovule in each, narrowly winged; style usually very short, occasionally up to 7 mm. and then curved in the bud. *Fruit* 1-3 winged (usually one or two carpels being aborted and producing only rudimentary wings); the winged carpels or samarae asymmetric, about 3 cm. long and 1·25-1·5 cm. broad, rigid, prominently veined, one-seeded, indehiscent, glabrous within; seed ovoid, hard, brown.

NOTE.—Unknown to the author until recently, this tree was discovered by Mr. F. S. Laughton, of the Department of Agriculture and Forestry, " in November, 1933, in Humansdorp Division, on steep slopes, above Baviaans Kloof River in shallow Bokkeveld soil." His specimens had been studied by Dr. J. Hutchinson and Dr. H. G. Fourcade, who recognised it as an interesting novelty. They were, however, handicapped by the absence of fruiting material, in view of which they generously waived their right to publish a description of the plant.

Although I am convinced that the Baviaans Kloof and the Longmore plants are the same species, there are certain differences. Whereas the specimens dissected by me all showed a 3-celled ovary, those dissected by Dr. Hutchinson and Dr. Fourcade had 3-5 cells; further, the inflorescences examined by me showed a greater range in development, some being considerably exserted from the leaves.

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SWARD DENSITY AND WEED INVASION OF WOOLLY FINGER (PRETORIA SMALL) PASTURES UNDER DIFFERENT GRAZING TREATMENTS

BY

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Department of Agricultural Botany, University of Pretoria.

With 7 Text Figures.

Read 5 July, 1937.

The work embodied in this paper was conducted at the experimental farm of the University of Pretoria, and consisted of two experiments, here referred to as A and B. The first (Experiment A) was laid out by Mr. W. R. Thompson, lecturer in Agronomy, and Mr. E. S. Dawson, farm manager. The second (Experiment B) by Mr. Bonsma, lecturer in Animal Husbandry, and Mr. Dawson. In both experiments the pastures were planted three years in advance, and were given applications of 150 lbs. superphosphate and 150 lbs. sulphate of ammonia per acre per annum both before and during the experiments.

Experiment A.

The object of this experiment was to study the reactions of "Woolly Finger" grass pastures to varying intensities of defoliation, and was conducted over a period of three years.

The treatments were as follows:—

(a) Light intermittent grazing.

(b) Heavy intermittent grazing.

(c) Continuous moderate intermittent grazing throughout the summer.

The treatments were duplicated, each plot being a third of an acre.

As the experiment was of a preliminary nature the above schedule was not strictly adhered to. Unfortunately the soil was not identical, the plots being either on a red loam or a grey clay. Pantograph quadrats indicated that the average basal cover in all the plots was ± 40 per cent. This was not in conformity with the observations outlined below, which clearly indicates that both vigour and growth were markedly influenced.

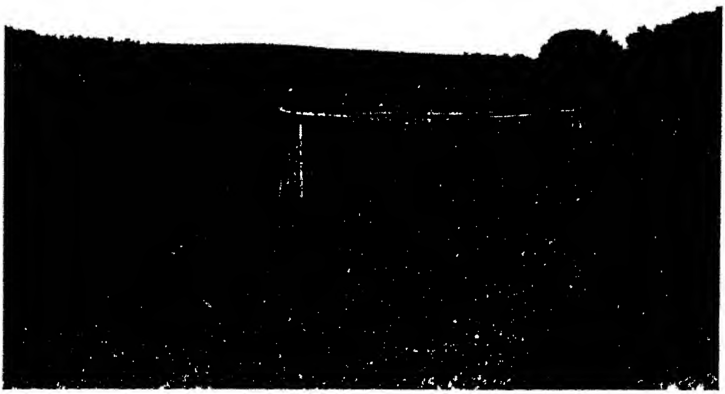
(a) *Light intermittent grazing.* (Plots 1 and 6.)

The plots exhibited a good "top hamper," and there was no evidence of weeds or other indications of over-grazing (see Photo 1), especially on plot 1 on red loam. Plot 6, however, on the clayey soil, carried a few weeds, such as *Verbena officinalis*, *Conyza* sp. and *Asclepias fruticosa*.

EXPERIMENT A.

[Photo by J M. Hector

Photo 1.—Light intermittent grazing. Loam.
NOTE: 1. Evenness of sward.
2. Absence of weeds.



[Photo by J. M. Hector.

Photo 2.—Heavy intermittent grazing. Loam.
NOTE: The occurrence of weeds.

(b) *Heavy intermittent grazing.* (Plots 2 and 5.)

" Top hamper " was again good, but inferior to that on plots 1 and 6. More weeds of the above species developed, particularly in plot 5, on the clayey soil.

(c) *Continuous moderate grazing.* (Plots 3 and 4.)

These plots were badly infested with the above weeds, plot No. 4 on clay again being worse than plot No. 3 on the loam. " Top hamper " was poor, but where the weeds were most abundant, the sward had ultimately been protected from grazing and the grass was longer.

EXPERIMENT A.

[Photo by J. M. Hector.

Photo 3.—Continuous moderate grazing. Clay.
NOTE: Great abundance of weeds.

It may be concluded that:

1. Light intermittent grazing (treatment a) showed less detrimental effects on the sward than heavy intermittent grazing and also continuous moderate grazing (treatments b and c).

2. None of the treatments, however, can be regarded as satisfactory from the grazing standpoint.

3. That weed development was more intensive on the clay soils than on the red loams.

EXPERIMENT B.

This experiment is in many respects similar to the previous, and for this reason only a brief description is given. The object

was to determine the value of woolly finger grass as summer and winter pasture for sheep, and to study the effect on the sward of the following systems of grazing.

EXPERIMENT B.

[Photo by J. M. Hector.

Photo 4.—Heavy grazing in spring and early summer, followed by light grazing in summer and autumn.

NOTE: Abundance of weeds and large scattered tussocks.

[Photo by J. M. Hector.

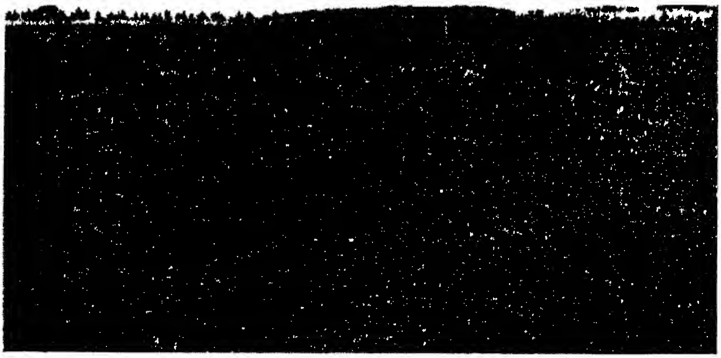
Photo 5.—Light grazing in spring and early summer, followed by heavy grazing summer and autumn.

NOTE: Shorter appearance of sward.

The treatments were as follows :—

1. Heavy grazing in spring and early summer followed by light grazing in late summer and autumn.
2. Light grazing in spring and early summer followed by heavy grazing in late summer and autumn.
3. Continuous moderate grazing.
4. Light grazing in spring and then rested for winter grazing.

EXPERIMENT B.



[Photo by J. M. Hector.

Photo 6.—Continuous moderate grazing.
NOTE: Sward shortest of all.

At the commencement of the experiment 12 sheep per camp every alternate week were used for heavy grazing; four sheep per camp every alternate week for light grazing; four sheep per camp continuously for continuous grazing; 12 sheep per camp for winter grazing. This rate of stocking, however, had afterwards to be modified to meet the fluctuating growth of the sward.

(a) Treatment 1. (Heavy grazing followed by light.)

Weeds such as *Conyza* sp., *Gomphrena globosa*, *Schkuria bonariensis*, and *Indigofera* sp. developed abundantly. Though quadrats did not give any definite differences, observations showed that " top hamper " was uneven and hard ungrazed tussocks numerous.

(b) Treatment 2. (Light grazing followed by heavy.)

Weeds were fewer in number and " top hamper " was fairly even, though shorter than in treatment 1.

(c) Treatment 3. (Continuous moderate grazing.)

Weeds were less abundant; " top hamper " was fairly even but shorter than in treatments 2 and 4.

(d) Treatment 4. (Light grazing in spring and then reserved for winter grazing.)

Here there were no weeds; the individual tussocks were large and the "top hamper" the best. The large, however, gave an uneven appearance to the sward.

EXPERIMENT B.

[Photo by J. M. Hector.

Photo 7.—Lightly grazed in spring, then rested for winter grazing.
NOTE: 1. Good "top hamper."
2. Large tussocks giving sward an uneven appearance.

It may be concluded:

1. That heavy grazing, followed by light grazing, induced an abundance of weeds, but had less detrimental effects on the sward than light grazing followed by heavy or continuous moderate grazing.

2. That the plots lightly grazed in spring, and then rested for winter grazing, showed no weed growth and had the best "top hamper." (Yet on account of the size of the tussocks the plots appeared uneven.)

The general conclusion might therefore be made that this treatment (No. 4) is satisfactory. It is, however, open to criticism. Up to the present no serious harm can be detected. Nevertheless, there is some evidence that this sward, depleted of its reserves in winter, will, in course of time, be unable to withstand the subsequent early spring grazing and as a consequence will deteriorate.

ACKNOWLEDGMENTS.

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A CONTRIBUTION TO THE ECOLOGY OF THE HIGHVELD FLORA

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With 16 Text Figures.

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Introducton.

The work embodied in this paper was carried out on Frankenwald, the Botanical Research Station of the University of the Witwatersrand.

This station is situated twelve miles from Johannesburg, with its western boundary on the Pretoria Road.

It is undulating country, dissected from N.-S. by the Jukskei River.

The Geology of the Region.

The old granite underlying the Witwatersrand System covers all this area. Diabase dykes and crush zones (large quartz outcrops) most often with a N.-S. strike are common in the granite, and fairly large areas are rendered useless for cultivation by accumulations of ouklip or nodular iron (iron sesquioxide) at or near the surface of the soil. These accumulations of ouklip act as reservoirs, and are responsible for a large number of the moist sites during the wet season. Granite outcrops are numerous, though not prominent, as they are on some of the surrounding farms.

The soil is gritty and very poor, though the grass cover is high compared with other parts, but the veld is not rich in terms of food value. The mean annual rainfall of the region is ± 25 inches.

In listing the plants to be found on Frankenwald, these have been grouped according to the habitats in which they may be found.

The constitution of the different habitats described below is controlled by such factors as:—

(i) Disturbing factors: e.g., ploughing, overgrazing, and the making of roads and paths.

(ii) Edaphic factors: e.g., watercourses, soil fertility, and soil texture.

It will be seen that in some cases the same plants appear in different sites, thus indicating that these plants have a wider environmental range than others which are restricted to one type of habitat only. For example: *Andropogon appendiculatus* is

1.
Typical homogeneous appearance of Undisturbed Veld.

2.
Protea hirta in background.

3.
Granite Outcrop, showing *Myrothamnus*.

confined solely to regions having a higher soil water content, for at least six months of the year, than that of the surrounding veld. *Justicia anagalloides*, on the other hand, may be found on *undisturbed veld, old lands, moist sites*, or *termitaria.*

Further acquaintance with the veld shows that it is not individual species which characterise the various sites, but the dominance of particular species together with their grouping. Where different successional stages merge into one another, a mixing of type species results; e.g., *Cynodon dactylon*, and *Trachypogon plumosus* on the same site.

Undisturbed Veld.

This term is applied to veld which shows no signs of disturbance such as ploughing, road making, or extreme overgrazing and trampling. The more abundant species of this type are:—*Trachypogon plumosus*, *Heteropogon contortus*, *Eragrostis chalcantha*, *Elyonurus argenteus*, *Tristachya hispida*, *Tristachya Rehmannii*, and *Brachiaria serrata*. Here and there, however, it may merge into a comparatively pure stand of one or other of these constituents.

Intermingled with the grasses are monocotyledons and dicotyledons. The monocotyledons are usually evident in the early spring, while the dicotyledons become conspicuous as the season advances. Later in the season the luxuriant growth and abundant flowers of the grasses mask the appearance of other plants to some extent.

Rock Outcrops.

These usually consist of outcropping quartz veins or crush zones, or granite. Most of the plants found growing on them are early pioneers, the most important of which are:—*Myrothamnus flabellifolia*, *Selaginella rupestris*, *Aristida vestita*, several spp. of *Ipomoea; Tritonia petrophila*, and in some of the larger cracks where a lot of humus has collected, *Pellaea hastata*, *Mohria caffrorum*, several spp. sedge and *Crassula* may be found. *Ceropegia Randallii* and *Aloe transvaalensis* are occasionally found, but are more common on crush zones than on granite outcrops.

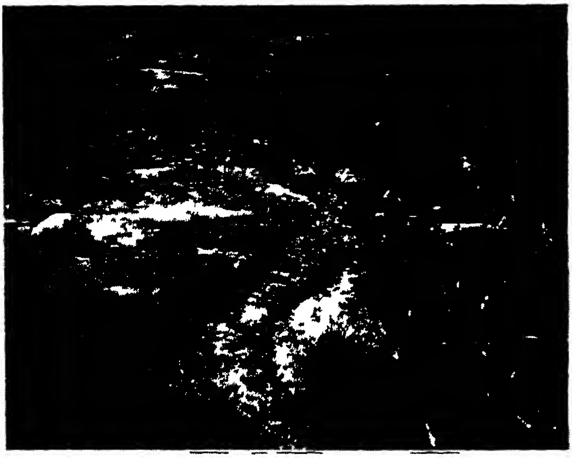
Around the edges of the outcrops where the soil is very shallow, and is very moist during the rainy season, *Sporobolus discosporus*, *Michrochloa caffra*, *Oropetium capense*, *Drosera* sp. and *Utricularia* spp. often occur.

Wet Sites.

The wet sites may be subdivided into (A) moist sites, and (B) watercourses and water holes.

A. *Moist Sites.*

These are caused by the approach of ouklip (iron sesquioxide or nodular iron) to within a few inches of the surface of the soil. In rainy seasons this impervious material acts as a reservoir and keeps the soil very moist almost throughout the year.



4.
Granite Outcrop, showing moist zone round edges with sedges, *Oropetium* and *Microchloa*.

5.
Quartz Outcrop or Crush Zone in Undisturbed Veld.

6.
Water Course. Showing *Hyparrhenia*, *Arundinella* and sedges.

The dominant species on these sites are:—Several spp. of *Cyperus*, *Aristida angustata*, *Monocymbium ceresiiforme*, *Haplocarpa scaposa*, *Helichrysum leipodium*, *Helichrysum nudifolium*, *Senecio succosus*, *Helichrysum aureonitens*.

B. *Watercourses and Water Holes.*

All the species found on moist sites are found along the watercourses, the main difference in the case of the watercourses, however, is the abundant growth of *Arundinella Ecklonii*, *Imperata cylindrica*, and *Hyparrhenia hirta*.

The edges of stagnant pools and water holes are usually overgrown with *Typha australis*, *Phragmites communis*, and *Scirpus corymbosus*. Water holes are usually confined to watercourses, but are sometimes found further inland where holes have been dug on moist sites.

Disturbed Areas.

A. *Old Roads.*

The most conspicuous feature of veld roads which have recently fallen in disuse, is the fact that a large number of indigenous veld plants appear before the weeds and certain grasses which are known to be the first plants to colonise such areas.

The highveld grasses, which appear to spread more by vegetation regeneration than by seed, are mainly bunch grasses. The tussocks of these grasses become worn down by the traffic and die out.

The plants which shoot up almost as soon as traffic ceases on these roads are usually found not to be young plants, but shoots from old bulbs, underground stems, and tubers. These underground stems and tubers seem to possess a capacity for remaining dormant for some years.

Plants of this type are:—*Albuca pachychlamus*, *Cyanotis nodiflora*, *Elephantorrhiza elephantina*, *Zizyphus zeyheriana*, *Raphionacme divaricata*, *Ipomoea crassipes*, *Ipomoea simplex*, and *Ipomoea bathicolpos*.

Some of the weeds, which appear soon in large numbers, are chiefly:—*Tagetes minuta*, *Solanum* spp., *Ursinea annua*, *Senecio laevigatus*, *Schkuhria bonariensis*, *Amaranthus Thunbergii*, *Eleusine indica*, *Aristida barbicollis*, *Tragus racemosus*.

B. *Termitaria, Rat Holes, and Meerkat Colonies.*

These sites are usually overgrown with *Cynodon dactylon* and *Eragrostis* spp., but some of the so-called climax grasses such as *Cymbopogon*, *Themeda*, and *Hyparrhenia* are often found in them. Thorny growths of *Zizyphus zeyheriana* are common, as are weeds, together with some of the indigenous shrubs such as *Vernonia Kraussii*, *Solanum capense*, *Justicia anagalloides*, and *Ipomoea* spp.

7.
Water Course. Showing *Digitaria*, *Hyparrhenia* and *Leucosidea* in background.

8.
Old Road. Showing *Elephantorrhiza*, *Acalypha* and *Ipomoea*.

9.
Old Termitarium. Showing ring of *Solanum capense* (at arrow).

C. *Overstocked Areas.*

Overstocking usually results in overgrazing and trampling.

Evidences of this are the disappearance of the " undisturbed veld " grasses, followed by an influx of pioneer grasses and weeds.

In Spring, large numbers of monocotyledons appear, due to the resistance of their bulbs to trampling, while later in the season, dicotyledons, with large underground systems, become conspicuous for the same reason as that on the old roads.

D. *Old Ploughed Lands.*

The first floral inhabitants of old ploughed lands are weeds, such as *Tagetes*, *Amaranthus*, *Alternanthera repens*, *Gomphrena globosa*, *Tribulus terrestris*, *Xanthium*, and *Datura stramonium.* Simultaneously with, or slightly after, comes a dense growth of *Cynodon dactylon* followed by *Aristida*, *Pogonarthria*, and *Eragrostis* spp.

It must be noted, however, that *Pentanisia*, *Rhynchosia*, *Tephrosia*, *Euryops*, *Dimorphotheca*, *Callilepus leptophylla*, *Ipomoca* spp. and *Raphionacme divaricata*, together with many others are frequently found growing on old ploughed lands. This is due to their ability to shoot from ploughed-up tubers. Often the reploughing of old lands results in the stimulation of dormant seeds of *Xanthium* and *Tagetes*, resulting in a luxuriant growth of these weeds.

Scrub Relics.

The scrub relics on Frankenwald are of four kinds:—

(1) *Protea and Other Species Open Woodland.*

(2) *Acacia Scrub.*

(3) *Scrub on Granite Outcrops.*

(4) *Watercourse Scrub.*

Protea scrub appears to be hardier than the *Acacia type*, and is found in more exposed places, such as the windward side of a hill. The individual trees of this type grow far apart, and are seldom, if ever, found growing in close association with dense *Acacia scrub*, though the *Acacia scrub* constituents are sometimes found loosely intermingled with the *Protea type*, and it has been observed that seedlings of *Acacia*, *Rhus*, *Zizyphus*, *Erhetia*, etc., are often found growing under *Proteas*, thus indicating that *Protea scrub* is probably the nursery of the denser *Acacia scrub*.

Rock scrub is not very extensive, and is usually confined to the protection of local groups of boulders. In most cases the species constituting *rock scrub* are the same as those of *Acacia scrub*.

The presence of *Acacia scrub* seems to be dependent on certain edaphic and protective factors, such as uneven rocky soil or soil of a different chemical and physical composition from the surrounding regions. It is contended by Professor John Phillips

10.
Old Termitarium. Showing *Solanum* sp. and *Cymbopogon* on site of old termitarium.

11.
Open Woodland. *Protea*: other spp. in Undisturbed Veld; *Protea caffra* in background.

12.
Rock Scrub. Showing *Royena* with circle of *Rhus discolor* round rocks.

that protection from fire is one of the most important factors governing the presence of *Acacia scrub*.

Acacia scrub is often found extensively along watercourses as is the case inside the Modderfontein boundary, but on Frankenwald, *Leucosidia scrub* dominates along the watercourses.

Acacia scrub is very rich in species, whereas, *Protea scrub* and *Watercourse scrub*, except for the presence of *Protea hirta* and *Leucosidea sericea*, does not differ much in composition from *Undisturbed veld*, and watercourses as previously listed.

PHENOLOGY.

Phenology is in the author's opinion of fundamental importtance in the study of veld management problems. The reasons for this statement are:—

1. Certain plants such as *Elyonurus argenteus* and *Tristachya Rehmannii* are useless from the grazing point of view, and since they are very early shooters, grazing them early causes an exhaustion in their root reserves, with the result that their growth can be greatly retarded in this way without seriously hampering the better grasses which shoot later. Phenological knowledge is essential for this.

2. A knowledge of the phenology of the veld is of infinite value in (a) the collection of pollen for the study of hay fever; (b) the collection of seeds for seed testing and germination experiments.

The general times of shooting and flowering do not seem to be influenced by the application of fertilizers. It is the time of shooting rather than the time of flowering that is influenced to a greater or lesser degree by such treatments as burning, mowing, and grazing. The effects of these treatments on veld are dependent upon the time and extent to which they have been applied. Also, shooting periods vary from year to year, according to the amount of rainfall during the previous rain periods and whether the previous winter has been severe, whether the last frosts have been late or whether it has been mild, and there have been early rains. Early rains followed by a drought have a very detrimental effect upon the veld, since the rain induces profuse shooting which cannot be maintained owing to the ensuing drought, and results in a serious exhaustion of reserves, which causes a setback to the veld for the coming season, even though the drought may be followed by good rains.

A point of interest to be noted here is that most of the monocotyledons (not including the grasses) are very early shooters and flowerers, and fade into obscurity after October. A few, such as *Tulbaghia leucantha* and *Hypoxis Rooperi* have a long flowering period, commencing early and ending late, while others such as *Eulophia Zeyheri* and *Satyrium cristatum* do not begin to flower until January, and their flowering period does not last more than a month.

13

Water Course Scrub Showing *Hyparrhenia* and *Digitaria* in foreground and *Leucosidea* in background

16

Rock Scrub Showing over-grazed veld in foreground Note adherence of scrub to line of strike

15

Acacia—Other spp Showing trampled Cynodon-veld in foreground

Actually, the flowering periods for all the veld plants may be divided into four types, namely:—(1) Early flowerers; (2) early flowerers with a long flowering period; (3) plants which flower approximately in the middle of the season; and (4) plants which flower late in the season.

It is of interest to note that of all the highveld grasses *Trachypogon plumosus* shoots early and flowers latest, but this does not apply to *Trachypogon plumosus* on the Brixton Ridge in Johannesburg; for there it is profusely in flower in early January, which is almost a month ahead of that on Frankenwald.

Since there are a number of characters which influence the phenology of the veld, it has been thought best to supply general phenological information where possible. Most of the phenological work has been carried out on veld management experiments.

A point of interest brought out by these observations over a period of years is the occurrence of seasonal flushes of flowers of different species in different years. For instance, in the summer of 1933-1934, there was a marked flush of *Senecio venosus* in certain parts of Frankenwald. During the same summer it was observed that local patches of *Digitaria tricholaenoides* flowered very profusely. While *D. tricholaenoides* is still conspicuous during its flowering period, it has not flowered as profusely as during the period 1933-1934.

Themeda triandra was not at all evident during the period 1933-1934, because very few flower heads were observed, but since then the number of flowers has become increasingly evident, and it was thought that the percentage of *Themeda* had increased considerably. Quadrat results, however, indicate that there has been little or no variation in the percentage of *Themeda* on Frankenwald.

In 1933-1934 there were occasional plants of *Lobelia rosulata* found on moist sites. Since then, the number of plants has increased so considerably that in the early part of the summer large areas of veld are so profusely covered that they assume a blue colour, which can be observed from some distance. These flushes of *Lobelia* do not seem to be confined to Frankenwald alone, but were also particularly conspicuous along the road between Pretoria and Warmbaths in December, 1936.

Procedure for Taking Phenological Observations.

1. It was noted that the period between August and November is a critical time in the growth of the veld, so that observations were made as frequently as possible, preferably once a week.

The following observations were made:—

(a) The occurrence of all the important species, with information as to shooting, flowering or fruiting; (b) the reactions to

climatic phenomena such as drought, frost and rain; (c) the apparent reactions to treatments such as grazing, trampling, burning and mowing.

2. Between November and March, veld reactions took place much more slowly, so that observations were taken less frequently, e.g., approximately once every fortnight.

3. From March to June was another critical period, so that it was again necessary to take frequent observations since changes in the veld took place rapidly.

14.

Acacia—Other spp. Showing adherence of scrub to rock outcrop and undisturbed veld in foreground.

LIST OF ABBREVIATIONS.

Very abundant	... = v. ab.	Locally frequent	... = loc. fr.
Abundant ...	... = ab.	Occasional ...	... = occ.
Fairly abundant	... = f. ab.	Fairly occasional	... = f. occ.
Locally abundant	... = loc. ab.	Very occasional	... = v. occ.
Frequent ...	... = fr.	Rare	... = rare.

PTERIDOPHYTA.

Polypodiaceae.

Pellaea hastata Link. Found on rock outcrops; occ.

Schizaceae.

Mohria caffrorum. Rock outcrops; v. occ.

Lycopodiaceae.

Selaginella rupestris Spreng. Rock outcrops; loc. v. ab. (usually forms a " mat ").

MONOCOTYLEDONAE.

Typhaceae.

Typha australis Schum. & Thourn. Watercourses and water holes; loc. ab.

GRAMINEAE.

Andropogoneae.

Andropogon amplectens Nees. Undisturbed veld; occ. to fr. Old roads and old termitaria; loc. fr. to loc. ab. Shoots, Sept.; flowers, Jan.; fruits and seeds, Jan. to Feb.

Andropogon appendiculatus Nees. Moist sites; loc. ab. Water holes and watercourses; loc. fr. to loc. ab. Shoots, Aug. to end of Sept.; flowers, Dec. to end Jan.; fruits and seeds, Jan. to Mar.

Andropogon eucomis Nees. Moist sites; loc. fr. Water holes and watercourses; loc. fr. Shoots, Sept.; flowers, mid-Jan. to Mar.; fruits and seeds, Feb. to end of Mar.

Andropogon huillensis Rendle. Moist sites; loc. fr. Water holes and watercourses; loc. occ. to loc. fr. Shoots, Sept.; flowers, mid-Dec. to end Jan.; fruits and seeds, Jan. to March.

Cymbopogon Spreng.

Cymbopogon excavatus (Hochst.) Stapf. Rock outcrops; occ. to loc. fr. Shoots, Sept.; flowers, Jan.-Feb.; fruits and seeds, Feb. to end Mar.

Cymbopogon plurinodis Stapf. ex Burtt Davy. Undisturbed veld; occ. to loc. fr. Old ploughed lands and old termitaria; occ. to loc. fr. Shoots, late Aug. or early Sept.; flowers, mid-Jan. to Feb.; fruits and seeds, Feb. to Mar.

Elyonurus argenteus Nees. Undisturbed veld; fr. to loc. ab. Shoots, late Aug. to Sept.; flowers, Nov.-Jan.; fruits and seeds, Dec. to Feb.

Haemarthria fasciculata Kunth. Watercourses and water holes; loc. fr. to loc. ab.

Heteropogon contortus (Linn.) Roem. and Schultz. Undisturbed veld; fr. to loc. v. ab. Shoots, Sept.; flowers, Jan.; fruits and seeds, Feb. to Mar.

Hyparrhenia aucta Stapf. Banks of watercourses; loc. fr. to loc. ab. Shoots, Sept.; flowers, Jan. to Feb.; fruits and seeds, Feb. to Mar.

Hyparrhenia hirta Stapf. Banks of watercourses; loc. fr. to loc. v. ab. Old roads; loc. fr. to loc. ab. Old ploughed lands, loc. v. ab. (*H. hirta* is often an indicator of some remote disturbance.) Shoots, Sept.; flowers, Jan. to Feb.; fruits and seeds, Feb. to Mar.

Imperata cylindrica Beauv. Water holes, watercourses and moist sites; loc. fr. to loc. v. ab. Shoots, Sept.; flowers, Dec. to mid-Jan.; fruits and seeds, Jan. to Feb.

Monocymbium ceresiiforme (Nees) Stapf. Moist sites; fr. to loc. ab. Undisturbed veld; occ. Rock outcrops; occ. Shoots, Sept.; flowers, Feb. to Mar.; fruits and seeds, Mar. to Apr.

Schizachyrium semiberbe Nees. Old roads; fr. to loc. ab. Rock outcrops; occ. to loc. fr. Undisturbed veld; occ. (*S. semiberbe* is an indicator of remote disturbance.) Shoots, Sept.; flowers, Feb. to Mar.; fruits and seeds, Mar. to Apr.

Themeda triandra Forsk. Undisturbed veld; occ. to fr. Old termitaria; fr. to loc. ab. Shoots, Sept. to Oct.; flowers, mid-Dec. to mid-Jan.; fruits and seeds, Jan. to Mar.

Trachypogon plumosus Nees. Exclusively undisturbed veld; fr. to loc. v. ab. Shoots, Aug. to Sept.; flowers, mid-Feb. to Mar.; fruits and seeds, Mar. to Apr.

Urelytrum squarrosum Hack. Undisturbed veld; occ. to fr. Shoots, Sept.; flowers, Jan. to end Feb.; fruits and seeds, Feb. to Mar.

Zoysieae.

Perotis indica (Linn.) Kuntze. Old roads; loc. occ. to loc. ab. Old ploughed lands; loc. occ. to loc. fr. Shoots, Sept.; flowers, Jan. to Feb.; fruits and seeds, Feb. to Mar.

Tragus racemosus (Linn.) Allioni. Old roads; loc. occ. to loc. fr. Old ploughed lands; loc. occ. to loc. ab. Shoots, Sept.; flowers, Nov. to Jan.; fruits and seeds, Jan. to Feb.

Tristegineae.

Arundinella Ecklonii Nees. Moist sites around water holes and on banks of watercourses; loc. fr. to loc. v. ab. Shoots, Sept.; flowers, Dec. to Jan.; fruits and seeds, Jan. to end Feb.

Paniceae.

Brachiaria.

Brachiaria nigropedata Stapf. Moist sites; loc. occ. Rock outcrops; loc. v. occ. Shoots, Sept.; flowers, Dec. to mid-Jan.; fruits and seeds, Jan. to Feb.

Brachiaria serrata (Spreng) Stapf. Undisturbed veld; fr. to v. ab. Shoots, Sept.; flowers, Dec. to mid-Jan.; fruits and seeds, Jan. to Feb.

Digitaria Rich.

Digitaria eriantha Steud. var. Steyn's. Old termitaria, banks of watercourses; loc. ab. Shoots, Sept.; flowers, Jan. to Feb.; fruits and seeds, Feb. to Mar.

Digitaria horizontalis Willd. Annual on old roads; occ. to fr. Old ploughed lands; occ. to loc. ab. Old termitaria; occ.

Digitaria tricholaenoides Stapf. Undisturbed veld; loc. fr. to loc. v. ab. Old roads and paths; loc. occ. to loc. ab. (forms "mat").

Panicum Linn.

Panicum coloratum Linn. Old ploughed lands; loc. fr. to loc. ab. Shoots, Sept.; flowers, Dec. to Jan., fruits and seeds, Jan. to Feb.

Panicum laevifolium Hack. Annual on old ploughed lands; occ. to v. ab. Old roads and old termitaria; occ. to fr.

Panicum natalense Hochst. Undisturbed veld; occ. to loc. fr. Shoots, Sept.; flowers, Jan. to Feb.; fruits and seeds, Feb. to Mar.

Paspalum Linn.

Paspalum dilatatum Poir. Moist sites and banks of watercourses. Shoots, Aug. to Sept.; flowers, Jan. to Feb.; fruits and seeds, Feb. to Mar.

Paspalum scrobiculatum Linn. Moist sites and banks of watercourses. Shoots, Aug. to Sept.; flowers, Jan. to Feb.; fruits and seeds, Feb. to Mar.

Paspalum vaginatum Swartz. Water holes and watercoures; often growing in the water; occ. to loc. v. ab. (forming a "mat").

Pennisetum geniculatum Jacq. Water holes and watercourses; occ. to loc. fr. Shoots, Sept.; flowers, Dec. to Jan.; fruits and seeds, Jan. to Feb.

Rhyncelytrum roseum (Nees) Stapf & Hubbard. Old ploughed lands; fr. to ab. Old roads; occ. to fr. Old termitaria; occ. Shoots, Sept.; flowers, Jan. to Mar.; fruits and seeds, Feb. to Apr.

Rhyncelytrum setifolium Choiv. Rock outcrops and undisturbed veld; occ. to loc. fr. Shoots, Sept.; flowers, Jan. to Feb.; fruits and seeds, Feb. to Apr.

Setaria Beauv.

Setaria aurea Hochst. Moist sites, watercourses and water holes; occ. to loc. ab. Shoots, Sept.; flowers, mid-Dec. to mid-Jan.; fruits and seeds, Jan. to Feb.

Setaria flabellata Stapf. Moist sites and old termitaria; loc. fr. to loc. ab. Shoots, Sept.; flowers, Dec. to Jan.; fruits and seeds, Jan. to Feb.

Setaria nigrirostris Dur & Schinz. Water holes; occ. Old termitaria; occ. to fr.

Setaria perennis Hack. Old termitaria; occ. to fr.

Setaria rubiginosa. Moist sites; occ. to fr. Shoots, Sept.; flowers, Jan.; fruits and seeds, Jan. to Feb.

Urochloa helopus. Annual. Old roads; occ. Old termitaria; occ. Old ploughed lands; occ. to loc. ab.

Oryzeae.

Leersia hexandra Swartz. Water holes; fr. to loc. v. ab. Watercourses; fr. to loc. v. ab.; often growing in water. Shoots, Aug.; flowers, Jan. to Feb.; fruits and seeds, Feb. to Mar.

Phalarideae.

Phalaris canariensis Linn. Exotic. Old ploughed lands; occ.

Agrostideae.

Aristida Stapf.

Aristida angustata Stapf. Rock outcrops; loc. fr. Moist sites; loc. fr. to loc. ab. Shoots, Sept.; flowers, Dec. to end Jan.; fruits and seeds, Jan. to Feb.

Aristida barbicollis Trin. & Rupr. Old roads; occ. to fr. Old termitaria; occ. to fr. Old ploughed lands; fr. to v. ab. Shoots. Sept.; flowers, Nov. to end Jan.; fruits and seeds, Dec. to Feb.

Aristida scabrivalvis Hochst. Rock outcrops; occ.

Aristida vestita Thunb. Rock outcrops; occ.

Sporobolus R. Br.

Sporobolus centrifugis Nees. Rock outcrops; occ. to fr.

Sporobolus discosporus Nees. Moist sites; occ. to loc. fr. Rock outcrops; occ. to loc. fr. Shoots, Sept.; flowers, Nov. to Jan.; fruits and seeds, Dec. to Jan.

Sporobolus fimbriatus Nees. Rock outcrops; occ. to fr. Undisturbed veld; occ. to loc. fr.

Sporobolus indicus Nees. Old ploughed lands; occ. to loc. fr. Old termitaria; occ. Shoots, Sept.; flowers, Dec. to Feb.; fruits and seeds, Jan. to Mar.

Aveneae.

Avenastrum turgidulum Stapf. Watercourses; occ. Water holes; occ. Moist sites; occ. Shoots, Sept.; flowers, Dec. to Jan.; fruits and seeds, Jan. to Feb.

Trichopteryx simplex Benth. Moist sites; occ. Rock outcrops; occ.

Tristachya hispida (Thunb.) Schum. Undisturbed veld; fr. to ab. Shoots, Sept.; flowers, Dec. to Jan.; fruits and seeds, Jan. to Feb.

Tristachya Rehmannii Hack. ex Schinz. Undisturbed veld; occ. to fr. Shoots, Aug. to Sept.; flowers, Dec. to Jan.; fruits and seeds, Jan. to Feb.

Festucaceae.

Diplachne biflora Hack. Undisturbed veld; occ. to loc. fr. Shoots, Sept.; flowers, Jan. to Feb.; fruits and seeds, Feb. to Mar.

Eragrostis Beauv.

Eragrostis abyssinica Link. Annual. Old ploughed lands; occ. to loc. fr.

Eragrostis annulata Chiov. Annual. Old ploughed lands; loc. fr. to v. ab. Old termitaria; occ.

Eragrostis aspera Nees. Old termitaria; occ. to loc. fr. Shoots, Sept.; flowers, Dec. to Feb.; fruits and seeds, Jan. to Mar.

Eragrostis brizoides Nees. Moist sites; occ. to loc. ab. Undisturbed veld; occ. to fr. Shoots, Sept.; flowers, Dec. to Feb; fruits and seeds, Jan. to Mar.

Eragrostis chalcantha Nees. Undisturbed veld; fr. to ab. Moist sites; fr. to v. ab. Shoots, Aug. to Sept.; flowers, Nov. to Feb.; fruits and seeds, Dec. to Feb.

Eragrostis chloromelas Steud. Old ploughed lands, old roads, and old termitaria; fr. to loc. v. ab. Shoots, Sept.; flowers, Dec. to Feb.; fruits and seeds, Jan. to Mar.

Eragrostis curvula Nees. Old ploughed lands, old roads, and old termitaria; fr. to loc. v. ab. Shoots, Sept.; flowers, Dec. to Feb.; fruits and seeds, Jan. to Mar.

Eragrotis denudata Hack. Rock outcrops; loc. fr. Shoots, Sept.; flowers, Dec. to Jan.; fruits and seeds, Jan. to Feb.

Eragrostis Galpini Steud. Moist sites; occ. to loc. fr. Shoots, Sept.; flowers, Jan. to Feb.; fruits and seeds, Feb. to Mar.

Eragrostis gummiflua Nees. Old roads; occ. to loc. ab. Rock outcrops; occ. to loc. fr. Old termitaria; occ. Old ploughed lands; occ. to loc. ab. Shoots, Sept.; flowers, mid-Dec. to Feb.; fruits and seeds, Jan. to Mar.

Eragrostis namaquensis Nees. Old roads; occ. Old termitaria; rare. Shoots, Sept.; flowers, Jan. to Feb.; fruits and seeds, Feb. to Mar.

Eragrostis nebulosa Stapf. Old roads; occ. to fr. Old termitaria; occ. Old ploughed lands; occ. to loc. fr. Shoots, Sept.; flowers, Dec. to Feb.; fruits and seeds, Jan. to Mar.

Stiburus Conrathii Hack. Moist sites; occ. to loc. ab. Shoots, Sept.; flowers, late Oct. to Nov.; fruits and seeds, Nov. to Dec.

Triraphis sp. Old termitaria; occ.

Chlorideae.

Chloris pycnothrix Trin. Old roads; occ. to fr. Old termitaria; occ. Old ploughed lands; occ. to fr.

Chloris virgata Swartz. Annual. Old roads; occ. to fr. Old termitaria; occ. to fr. Old ploughed lands; fr. to v. ab.

Cynodon dactylon Steud. Old roads; fr. to loc. ab. Old termitaria; loc. fr. to loc. v. ab. Old ploughed lands; fr. to v. ab. Shoots, Sept.; flowers, Dec. to Feb.; fruits and seeds, Jan. to Feb.

Eleusine indica Gaertn. Annual. Old roads; occ. to loc. ab. Old termitaria; occ. to fr. Old ploughed lands; fr. to v. ab.

Eustachys paspaloides Lanza & Matti. Rock outcrops; occ. to fr. Scrub relic; fr. to loc. ab. Shoots, Sept.; flowers, Dec. to Jan.; fruits and seeds, Jan. to Feb.

Harpechloa falx (Linn. f.) Kuntze. Moist sites; loc. ab. Undisturbed veld; loc. fr. to loc. ab. Shoots, Aug. to Sept.; flowers, late Nov. to mid-Dec.; fruits and seeds, Dec. to Jan.

Lophacme digitata Stapf. Moist sites; occ. to fr. Undisturbed veld; occ. Shoots, Aug. to Sept.; flowers, Dec. to Jan.; fruits and seeds, Jan. to Feb.

Microchloa caffra Nees. Undisturbed veld; occ. to fr. Rock outcrops; loc. ab. Shoots, Sept.; flowers, Dec. to Jan.; fruits and seeds, Jan. to Feb.

Hordeae.

Oropetium capense Stapf. Rock outcrops; loc. ab. Shoots, Sept.; flowers, Dec. to Jan.; fruits and seeds, Jan. to Feb.

CYPERACEAE.

Cyperus Linn.

Cyperus compactus Lam. Undisturbed veld; fr. Moist sites; fr. to ab. Shoots, Sept.; flowers, Dec. to Jan.; fruits and seeds, Jan. to Feb.

Cyperus compactus Lam. *var. flavissimus* C.B.Cl. Undisturbed veld; fr. Moist sites; fr. to ab. Shoots, Sept.; flowers, Dec. to Jan.; fruits and seeds, Jan. to Feb.

Cyperus esculentus. Moist sites; fr. to ab. Water holes and watercourses; fr. to loc. v. ab. Shoots, Aug. to Sept.; flowers, Dec. to Jan.; fruits and seeds, Jan. to Feb.

Cyperus fastigiatus Rotlb. Moist sites; fr. Water holes and watercourses; fr. Shoots, Sept.; flowers, Dec. to Jan.; fruits and seeds, Jan. to Feb.

Cyperus macranthus C.B.Cl. (*Pycreus umbrosus* Nees). Moist sites; fr. to loc. ab. Shoots, Sept.; flowers, Dec. to Jan.; fruits and seeds, Jan. to Feb.

Cyperus phaeorhizus K. Schum. Moist sites; fr. Water holes and watercourses; fr.

Xyridaceae.

Xyris Gerrardii N.E.Br. Moist sites; occ. Shoots, Sept.; flowers, Dec. to Jan.; fruits and seeds, Jan. to Feb.

Commelinaceae.

Commelina sp. Rock outcrops; occ. Moist sites; occ. Water holes and watercourses; occ. Shoots, Sept.; flowers, Dec. to Feb.; fruits and seeds, Jan. to Mar.

Cyanotis nodiflora Kunth. Undisturbed veld; occ. Rock outcrops; occ. Moist sites; occ. Shoots, Aug. to Sept.; flowers, Dec. to Jan.; fruits and seeds, Jan. to Feb.

Juncaceae.

Juncus exsertus Burch. Moist sites; occ. to fr. Water holes and watercourses; occ. to fr.

Juncus oxycarpus E. Mey. Moist sites; occ. to fr. Water holes and watercourses; occ. to fr.

Liliaceae.

Albuca pachychlamys Baker. Undisturbed veld; occ. to fr. Rock outcrops; occ. Moist sites; occ. to fr. Shoots, Aug.; flowers, Sept. to Oct.; fruits and seeds, Oct. to Nov.

Aloe transvaalensis (Ktze.) Schum. Rock outcrops; occ. to fr. Shoots, Aug.; flowers, Aug. to Sept.; fruits and seeds, Oct. to Nov.

Androcymbium Dregii Presl. Moist sites; occ. Shoots, Sept.; flowers, Feb. to Mar.; fruits and seeds, Mar. to Apr.

Anthericum MacOwani Baker. Moist sites; occ. to fr. Shoots, Sept.; flowers, Dec. to Jan.; fruits and seeds, Jan. to Feb.

Anthericum transvaalensis Baker. Moist sites; occ.

Asparagus sp. Scrub relic; occ. to fr.

Boweia volubilis Harv. Scrub relic; rare.

Bulbine sp. Undisturbed veld; occ. to fr. Moist sites; occ. to fr. Shoots, Aug.; flowers, Aug. to Sept.; fruits and seeds, Sept. to Nov.

Bulbinella sp. Undisturbed veld; rare to occ. Moist sites; rare to occ. Shoots, Aug.; flowers, Aug. to Sept.; fruits and seeds, Sept. to Nov.

Chortolirion subspicatum Berger. Undisturbed veld; occ. Moist sites; occ. Shoots, Aug.; flowers, Aug. to Sept.; fruits and seeds, Sept. to Nov.

Dipcadi oligotrichum Baker. Undisturbed veld; occ.; Shoots, Aug.; flowers, Sept. to Oct.; fruits and seeds, Oct. to Nov.

Eucomis undulata Ait. Rock outcrops; rare to occ. Moist sites; rare to occ. Shoots, Aug. to Sept.; flowers, Jan.; fruits and seeds, Jan. to Feb.

Kniphofia aloides Moench. Water holes and watercourses; rare. Shoots, Aug.; flowers, Dec. to Jan.; fruits and seeds, Jan. to Feb.

Ornithogalum sp. Old termitaria; occ. Undisturbed veld; occ. to loc. fr. Moist sites; occ. to loc. fr. Shoots, Aug. to Sept.; flowers, Nov. to Dec.; fruits and seeds, Dec. to Jan.

Scilla lanceaefolia Baker. Undisturbed veld; occ. Shoots, Aug. to Sept. flowers, Sept to Nov.; fruits and seeds, Nov. to Dec.

Scilla ovatifolia Baker. Undisturbed veld; occ. Shoots, Aug. to Sept.; flowers, Sept. to Nov.; fruits and seeds, Nov. to Dec.

Tulbaghia leucantha var, major. Undisturbed veld; occ. to fr. Moist sites; fr. to loc. ab. Shoots, Aug.; flowers, Sept. to March; fruits and seeds, Oct. to Apr.

Tulbaghia leucantha var, minor. Undisturbed veld; occ. to fr. Moist sites; fr. to loc. ab. Shoots, Aug.; flowers, Sept. to Mar; fruits and seeds, Oct. to Apr.

Urginea multisetosa Baker. Undisturbed veld; rare to occ. Moist sites; rare to occ. Shoots, Aug.: flowers, Sept. to Oct.; fruits and seeds, Oct. to Nov.

Urginea pretoriensis Baker. Undisturbed veld; rare. Moist sites; rare. Shoots, Aug.; flowers, Sept. to Oct.; fruits and seeds, Oct. to Nov.

Amaryllidaceae.

Anoiganthus breviflora Baker. Moist sites; rare to occ. Shoots, Aug.; flowers, Oct. to Nov.; fruits and seeds, Nov. to Jan.

Buphane toxicaria Thunb. Undisturbed veld; occ. to fr. Shoots, Aug.; flowers, Oct. to Nov.; fruits and seeds, Nov. to Dec.

Haemanthus magnificus Herb. Scrub relic and rock outcrops. Shoots, Aug.; flowers, Sept. to Oct.; fruits and seeds, Oct. to Nov.

Hypoxis filiformis Baker. Moist sites; occ. to loc. ab. Shoots, Aug.; flowers, Oct. to Feb.; fruits and seeds, Nov. to Feb.

Hypoxis rigidula Baker. Undisturbed veld; occ. Moist sites; occ. Shoots, Aug.; flowers, Dec. to Feb.; fruits and seeds, Jan. to Mar.

Hypoxis Rooperi Moore. Undisturbed veld; occ. to fr. Moist sites; occ. to loc. fr. Shoots, Aug.; flowers, Dec. to Feb.; fruits and seeds, Jan. to Mar.

Velloziaceae.

Vellozia retinervis. Rock outcrops; occ. to loc. fr. Shoots, Sept.; flowers, Jan. to Feb.; fruits and seeds, Feb. to Mar.

Iridaceae.

Babiana hypogea Burch. Undisturbed veld; rare to occ. Shoots, Aug.; flowers, Jan. to Feb.; fruits and seeds, Jan. to Mar.

Gladiolus crassifolius Baker. Undisturbed veld; rare to occ. Shoots, Aug. to Sept.; flowers, Dec. to Jan.; fruits and seeds, Jan. to Feb.

Gladiolus edulis Birch. Undisturbed veld; occ. Shoots, Sept.; flowers, mid-Dec. to Feb.; fruits and seeds, Jan. to Mar.

Hesperantha longicollis Baker. Moist sites, water holes and watercourses; fr. to loc. ab. Shoots, Aug.; flowers, Sept. to Oct.; fruits and seeds, Oct. to Nov.

Moreae trita N.E. Br. Undisturbed veld: occ. Shoots, Aug.; flowers, Aug. to Sept.; fruits and seeds, Sept. to Oct.

Tritonia petrophila Baker. Rock outcrops; occ. to loc. ab. Shoots, Sept.; flowers, Dec. to Feb.; fruits and seeds, Jan. to Mar.

Orchidaceae.

Eulophia R. Br.

Eulophia hians Sprengl. Moist sites; occ. to fr. Undisturbed veld; rare. Old termitaria; rare to occ. Shoots, Aug.; flowers, Sept to Oct. and Jan. to Feb.; fruits and seeds, Oct. to Nov., and Feb. to Mar.

Eulophia leontoglossa Reich. Moist sites; rare to occ. Rock outcrops; occ. Shoots, Aug.; flowers, Jan. to Feb.; fruits and seeds, Feb.

Eulophia Watkinsonii Rolf. E. Moist sites; rare to occ. Undisturbed veld; rare. Old termitaria; rare. Shoots, Aug.; flowers, Sept. to Oct.; fruits and seeds, Oct. to Nov.

Eulophia Zeyheri Hook. Moist sites; occ. Old termitaria; rare. Shoots, Aug.; flowers, mid-Dec. to Feb.; fruits and seeds, Jan. to Feb.

Satyrium cristatum Sond. Moist sites, water holes and watercourses; rare to occ. Shoots, Aug.; flowers, Jan. to Feb.; fruits and seeds, Feb. to Mar.

DICOTYLEDONAE.

Ulmaceae.

Celtis kraussiana. Scrub relic; occ. to fr.

Proteaceae.

Protea caffra Meisn. Scrub protea open woodland; fr. to ab. Flowers, Dec. to Jan.; fruits and seeds, Jan.

Protea hirta Klotzch. Undisturbed veld; occ. to loc. fr. Rock outcrops; occ. to loc. fr. Flowers, Dec. to Jan.; seeds and fruits, Jan.

Santalaceae.

Thesium transvaalense Schltr. Root parasite; undisturbed veld; occ. Shoots, Sept.; flowers, Dec.-Jan.; fruits and seeds, Jan. to Feb.

Loranthaceae.

Loranthus Zeyheri Harv. Scrub relic; parasite common on Protea caffra, etc.; occ. Shoots, Aug.; flowers, Aug. to Sept.; fruits and seeds, Sept. to Dec.

Viscum sp. Scrub relic. Tree parasite. Shoots, Aug.; flowers, Sept. to Oct.; fruits and seeds, Oct. to Dec.

Polygonaceae.

Polygonum nodosum Schust. Water holes and watercourses; occ. Shoots, Sept.; flowers, Dec. to Mar.; fruits and seeds, Jan. to Apr.

Polygonum tomentosum Willd. Water holes and watercourses; occ. Shoots, Sept.; flowers, Dec. to Mar.; fruits and seeds, Jan. to Apr.

Chenopodiaceae.

Chenopodium album Linn. Old termitaria; occ. Old roads; occ. Old ploughed lands; fr.

Chenopodium ambrosoides Linn. Old termitaria; occ. to fr. Old roads; occ. Old ploughed lands; occ. to fr.

Chenopodium foetidum Schrad. Old termitaria; rare. Old roads; rare. Old ploughed lands; occ.

Amarantaceae.

Achyranthus aspera Linn. Scrub relic; occ. to fr.

Alternanthera repens Steud. Old roads; occ. to ab. Old termitaria; occ. to fr. Old ploughed lands; fr. to v. ab.

Amaranthus Thunbergii Yog. Old roads; occ. to fr. Old termitaria; occ. Old ploughed lands: occ. to ab.

Phytolaccaceae.

Phytolacca americana Linn. Old ploughed lands; occ. Old roads; occ. Old termitaria; rare.

Psammotropha androsacea Fenzl. Rock outcrops; occ. Undisturbed veld; occ.

Psammotropha breviscapa Burtt Davy. Old ploughed lands; rare. Watercourses; rare. Undisturbed veld; v. rare.

Aizoceae.

Mesembryanthemum acutipetalum N.E. Br. Rock outcrops; rare to occ.

Portulacaceae.

Anacampseros sp. Rock outcrops; occ. to loc. fr.

Portulacca oleracea Linn. Annual weed. Old roads; occ. to fr. Old termitaria; fr. Old ploughed lands; fr. to v. ab.

Talinum caffrum E. & Z. Acacia scrub; occ. Rock outcrops; v. occ.

Caryophyllaceae.

Corrigiola littoralis Linn. Moist sites; occ. to fr. Old ploughed lands; occ. to loc. fr. Old roads; occ.

Dianthus mooiensis Williams. Undisturbed veld; occ. to fr. Shoots, Sept.; flowers, Oct. to Jan.; fruits and seeds, Dec. to Feb.

Pollichia campestris Ait. Old roads; occ. Old termitaria; occ. Old ploughed lands; occ.

Silene oliveriana Burch. Undisturbed veld; occ. to loc. fr. Old teritaria; occ. Old roads; occ. Old ploughed lands; occ. Shoots, Sept.; flowers, Nov. to Feb.; fruits and seeds, Jan. to Mar.

Ranunculaceae.

Clematis brachiata Thunb. Acacia scrub; occ. to fr.

Clematopsis Stanleyi Hutch. Rock outcrops; occ. Shoots, Sept.; flowers, Dec. to Feb.; fruits and seeds, Feb. to Mar.

Ranunculus Meyeri var. transvaalensis Sysz. Moist sites; rare to occ. Watercourses; rare to occ. Shoots, Sept.; flowers, Dec. to Feb.; fruits and seeds, Feb. to Mar.

Papaveraceae.

Argemone mexicana Linn. Old termitaria; v. occ. Old ploughed lands; occ. to ab. Old roads; occ. Shoots, Aug.; flowers, Sept. to Mar.; fruits and seeds, Oct. to Apr.

Papaver aculeatum Harv. Moist sites; occ. to fr. Watercourses; occ. Shoots, Sept.; flowers, Nov. to Feb.; fruits and seeds, Dec. to Mar.

Capparidaceae.

Cleome monophylla Linn. Rock outcrops; occ. to fr. Old roads; occ. Old termitaria; occ. Shoots, Sept.; flowers, Nov. to Feb.; fruits and seeds, Dec. to Mar.

Maerua triphylla Thunb. Acacia scrub and rock outcrops; occ. Shoots, Sept.; flowers, Jan. to Mar.; fruits and seeds, Jan. to Apr.

Cruciferae.

Lipidium linoides Thunb. Old roads; occ. to fr. Old termitaria; occ. Old ploughed lands; occ. to ab.

Droseraceae.

Drosera sp. Moist sites; occ. to loc. ab. Rock outcrops; occ. to fr.

Crassulaceae.

Crassula nodulosa Schoul. Rock outcrops; occ.

Kalanchoe sp. Rock outcrops; rare to occ. Acacia scrub; occ.

Crassula sp. Rock outcrops; fr. to ab.

Pittosporaceae.

Pittosporum viridiflorum Simms. Rock scrub; occ. Acacia scrub; occ.

Myrothamnaceae.

Myrothamnus flabellifolia Welw. Rock outcrops; occ. to ab.

Rosaceae.

Agrimonia eupatoria Linn. Watercourses; rare to occ.

Leucosidea sericea E. & Z. Watercourses; loc. fr. to loc. ab.

Parinarium capense Harv. Rock outcrops; loc. occ. to loc. ab. Undisturbed veld; occ. to loc. ab. Shoots, Sept.; flowers, Jan. to Feb.; fruits and seeds, Feb. to Apr.

Leguminosae.

Acacia (Tourn.) Linn.

Acacia caffra Willd. Protea open woodland; occ. Acacia scrub; occ. to fr. Shoots, Aug. to Sept.; flowers, Sept. to Oct.; fruits and seeds, Oct. to Feb.

Acacia Karroo Hayne. = *A. horrida* Willd. Acacia scrub; fr. to ab. Shoots, Sept.-Aug.; flowers, Sept. to Oct.; fruits and seeds, Nov. to Mar.

Acacia robusta Burch. Acacia scrub; occ. to fr. Shoots, Aug. to Sept.; flowers, Sept. to Oct.; fruits and seeds, Nov. to Mar.

Argyrolobium speciosum E. & Z. Undisturbed veld; occ. to rare. Watercourses; occ. to fr. Shoots, Sept.; flowers, mid-Dec. to Feb.; fruits and seeds, Jan. to Mar.

Cassia mimosoides Linn. Undisturbed veld; occ. Shoots, Sept.; flowers, Dec. to Feb.; fruits and seeds, Jan. to Mar.

Elephantorrhiza elephantina (Burch.) Skeels. Old roads; occ. to fr. Old termitaria; occ.; Undisturbed veld; occ. to loc. ab. Shoots, Aug.; flowers, Oct. to Nov.; fruits and seeds, Nov. to Apr.

Eriosema Desv.

Eriosema Burkei Benth. Undisturbed veld; v. occ. Shoots, Sept.; flowers, Oct. to Jan.; fruits and seeds, Jan. to Apr.

Eriosema cordatum E. Mey. Undisturbed veld; occ. Shoots, Sept.; flowers, Oct. to Jan.; fruits and seeds, Jan. to Apr.

Eriosema transvaalensis C. E. Moss (ined.) Undisturbed veld; occ. Shoots, Sept.; flowers, Oct. to Jan.; fruits and seeds, Jan. to Apr.

Erythrina Zeyheri Harv. Old roads; v. occ. Termitaria; occ. Shoots, Sept.; flowers, Dec. to Jan.; fruits and seeds, Jan. to Apr.

Indigofera Linn.

Indigofera hibrida N.E. Br. Undisturbed veld; occ. to fr. Shoots, Sept.; flowers, Dec. to Feb.; fruits and seeds, Jan. to Mar.

Indigofera oxitropis Benth. Undisturbed veld; occ. Shoots, Sept.; flowers, Dec. to Feb.; fruits and seeds, Jan. to Apr.

Indigofera sp. Undisturbed veld; occ.

Lotononis E. & Z.

Lotononis eriantha Baker. Undisturbed veld; occ. Shoots, Sept.; flowers, Jan. to Feb.; fruits and seeds, Feb. to Apr.

Lotononis foliosa Bolus. Undisturbed veld; occ. Shoots, Sept.; flowers, Jan. to Feb.; fruits and seeds, Feb. to Apr.

Lotononis orthorbiza Conrath. Undisturbed veld; occ. Old ploughed lands; occ. Shoots, Sept.; flowers, Jan. to Feb.; fruits and seeds, Feb. to Mar.

Pearsonia sessilifolia. Undisturbed veld; occ. Rock outcrops; occ. Shoots, Sept.; flowers, Dec. to Feb.; fruits and seeds, Jan. to Mar.

Rhynchosia nervosa Benth. Undisturbed veld; occ. Old roads; occ. to fr. Shoots, Sept.; flowers, Oct. to Feb.; fruits and seeds, Nov. to Mar.

Spenostylis angustifolia. Undisturbed veld; occ. to fr. Shoots, Aug.; flowers, Oct. to Feb.; fruits and seeds, Dec. to Mar.

Tephrosia aurantiaca R. G. N. Young. Undisturbed veld; occ. Shoots, Sept.; flowers, Dec. to Feb.; fruits and seeds, Jan. to Mar.

Vigna vexillata Benth. Undisturbed veld; occ. Watercourses; occ. Shoots, Sept.; flowers, Dec. to Feb.; fruits and seeds, Jan. to Mar.

Zornia tetraphylla Miche. Old roads; rare to occ. Shoots, Sept.; flowers, Dec. to Feb.; fruits and seeds, Jan. to Mar.

Geraniaceae.

Pelargonium aconitifolium var. angustisectum Kunth. Undisturbed veld; occ. Shoots, Sept.; flowers, Dec. to Feb.; fruits and seeds, Jan. to Mar.

Oxalidaceae.

Oxalis Linn.

Oxalis corniculata Linn. Moist sites; occ. to loc. ab. Old ploughed lands; occ. to ab. Shoots, Sept.; flowers, Oct. to Mar.; fruits and seeds, Dec. to Apr.

Oxalis semiloba. Old termitaria; occ. Moist sites; occ.

Oxalis setosa E. Mey. Undisturbed veld; occ. Moist sites; occ. to ab. Old ploughed lands; occ. Shoots, Sept.; flowers, Oct. to Feb.; fruits and seeds, Nov. to Mar.

Zygophyllaceae.

Tribulus terrestris Linn. Old roads; occ. to ab. Old ploughed lands; occ. to v. ab. Shoots, Sept.; flowers, Dec. to Feb.; fruits and seeds, Jan. to Mar.

Rutaceae.

Fagara magalismontana Engl. Rock scrub; occ. to fr. Acacia scrub; occ.

Polygalaceae.

Polygola.

Polygola abysinnica R. Br. Undisturbed veld; occ. to loc. fr. Shoots, Sept.; flowers, Nov. to Feb.; fruits and seeds, Dec. to Mar.

Polygola gracilenta Burtt Davy. Undisturbed veld; occ. Shoots, Sept.: flowers, Nov. to Feb.; fruits and seeds, Dec. to Mar.

Euphorbiaceae.

Acalypha.

Acalypha angustata Sond. Old roads; occ.; Undisturbed veld; occ. Shoots, Sept.; flowers, Dec. to Feb.; fruits and seeds, Jan. to Mar.

Acalypha caperonioides Baill. Old roads; occ. Undisturbed veld; occ. to loc. fr. Shoots, Sept.; flowers, Dec. to Feb.; fruits and seeds, Jan. to Mar.

Euphorbia.

Euphorbia striata Thunb. Undisturbed veld; occ. to fr. Shoots, Aug.; flowers, Oct. to Dec.; fruits and seeds, Nov. to Feb.

Euphorbia truncata N.E. Br. Undisturbed veld; rare to occ. flowers, Oct. to Nov.; fruits and seeds, Nov. to Jan.

Phyllanthus sp. Old roads; occ. Old ploughed lands; occ. to fr.

Anacardiaceae.

Rhus Tourn.

Rhus discolor E. Mey. Rock scrub; occ. to loc. ab.

Rhus Guenzii Sond. Acacia scrub; rare to occ.

Rhus Zeyheri Sond. Acacia scrub; rare to occ.

Celastraceae.

Gymnosporia buxifolia (Linn.) Szysz. Acacia scrub; fr. Comes into leaf, Sept; flowers, Oct. to Nov.; fruits and seeds, Dec. to Mar.

Rhamnaceae.

Zizyphus.

Zizyphus mucronata Willd. Acacia scrub; occ. Rock scrub; occ.

Zizyphus zeyheriana Sond. Old termitaria; fr. to loc. v. ab. Shoots, Aug. to Sept.; flowers, Oct. to Nov.; fruits and seeds, Dec. to Mar.

Tiliaceae.

Triumfetta Sonderi Fried & Ham. Old roads. Undisturbed veld; v. rare.

Malvaceae.

Hibuscus 3 spp. Undisturbed veld; occ. Shoots, Sept.; flowers, Nov. to Feb.; fruits and seeds, Jan. to Mar.

Sterculeaceae.

Dombeya rotundifolia Planch. Acacia scrub; occ. to fr. Rock scrub; occ. Shoots, Sept.; flowers, Sept. to Oct.; fruits and seeds, Nov. to Feb.

Hermannia.

Hermannia depressa N.E. Br. Old termitaria; occ. Shoots, Aug. to Sept.; flowers, mid-Sept. to Feb.; fruits and seeds, Oct. to Mar.

Hermannia lanceaefolia Szysz. Old termitaria; occ. to fr. Undisturbed veld; occ. to fr. Shoots, Aug. to Sept.; fruits and seeds, Oct. to Mar.; flowers, Sept.

Guttiferae.

Hypericum.

Hypericum aethiopicum Thunb. Old roads; occ. Undisturbed veld; occ. to fr. Shoots, Aug. to Sept.; flowers, Nov. to Feb.; fruits and seeds, Dec. to Mar.

Hypericum sp. Moist sites; occ. to loc. ab. Shoots, Aug. to Sept.; flowers, Nov. to Feb.; fruits and seeds, Dec. to Mar.

Elatinaceae.

Bergia decumbens Planch. Old roads; occ. to fr. Old ploughed lands; occ. to ab. Old termitaria; occ. to fr. Shoots, Sept.; flowers, Dec. to Feb.; fruits and seeds, Jan. to Mar.

Flacourtiaceae.

Dovyalis rhamnoides Harv. Acacia scrub; rare.

Thymeliaceae.

Gnidia Linn.

Gnidia caffra Neimr. Undisturbed veld; occ. to fr. Shoots, Aug.; flowers, Sept. to Jan.; fruits and seeds, Oct. to Feb.

Gnidia capitata Linn. Undisturbed veld; occ. to fr. Shoots, Aug.; flowers, Sept. to Jan.; fruits and seeds, Oct. to Feb.

Gnidia kraussiana Neissn. Undisturbed veld; occ. to fr. Shoots, Aug.; flowers, Sept. to Jan.; fruits and seeds, Oct. to Feb.

Gnidia microcephala Meisn. Undisturbed veld; occ. Shoots, Aug.; flowers, Sept. to Jan.; fruits and seeds, Oct. to Feb.

Melastomaceae.

Dissotis sp. Moist sites; occ. to loc. fr. Shoots, Aug.; flowers, Nov. to Jan.; fruits and seeds, Dec. to Feb.

Onagraceae.

Hartmannia rosea Ait. Watercourses; occ. to fr. Old ploughed lands; occ. to fr. Shoots, Aug.; flowers, Oct. to Mar.; fruits and seeds, Nov. to Apr.

Oenothera.

Oenothera biennis Linn. Old roads; occ. to fr. Watercourses; occ. to fr. Old ploughed lands; occ. to ab. Shoots, early Aug.; flowers, Sept. to Mar.; fruits and seeds, Oct. to Apr.

Oenothera biennis var. grandiflora Linn. Watercourses; occ.

Haloragidaceae.

Gunnera perpeusa Linn. Watercourses; occ.

Asclepiadaceae.

Brachystelma barberiae Harv. Acacia scrub; rare.

Brachystelma Galpini N.E. Br. Old termitaria; rare to occ. Undisturbed veld; rare.

Umbelliferae.

Heteromorpha arborescens Scham. Schlt. Watercourses; occ. Rock scrub; occ.

Hydrocotyle asiatica Linn. Moist sites; loc. v. ab. Watercourses; loc. v. ab.

Peucedanum magalismontanum. Undisturbed veld; occ. Shoots, Sept.; flowers, Dec. to Feb.; fruits and seeds, Jan. to Mar.

Myrsinaceae.

Myrsine africana. Rock scrub; occ.

Ebenaceae.

Euclea.

Euclea lanceolata E. May. Acacia scrub; occ. Rock scrub; occ.

Euclea undulata Thunb. Acacia scrub; occ. Rock scrub; occ.

Royena pallens Thunb. Acacia scrub; occ. to fr. Rock scrub; occ. to fr.

Oleaceae.

Olea verucosa Link. Rock scrub; occ.

Loganiaceae.

Chilianthus arboreus A.Dl. Acacia scrub.; occ. to fr.

Gomphostigma scoparioides. Watercouses; occ.

Gentianaceae.

Chironia humilis Gilg. Watercourses; occ. to fr. Moist sites; occ. Shoots, Sept.; flowers, Dec. to Feb.; fruits and seeds, Jan. to Mar.

Apocynaceae.

Carissa arduina Lam. Rock scrub; occ. Acacia scrub; occ.

Landolphia capensis. Rock scrub; occ.

Asclepiadaceae.

Asclepias Lindl.

Asclepias affinis Schltr. Undisturbed veld; occ. Shoots, Sept.; flowers, Dec. to Jan.; fruits and seeds, Jan. to Mar.

Asclepias aurea Schltr. Undisturbed veld; occ. Shoots, Sept.; flowers, Sept. to Jan.; fruits and seeds, Jan. to Mar.

Asclepias eminens Schltr. Undisturbed veld. Shoots, Sept.; flowers, Dec. to Jan.; fruits and seeds, Jan. to Mar.

Asclepias fruticosa Linn. Old roads; occ. Old ploughed lands; occ. to ab. Shoots, Sept.; flowers, Dec. to Jan.; fruits and seeds, Jan. to Mar.

Asclepias stellifera Schltr. Undisturbed veld; occ. Old ploughed lands; occ. to loc. ab. Shoots, Sept.; flowers, Oct. to Jan.; fruits and seeds, Dc. to Mar.

Araliaceae.

Cussonia spicata Thunb. Rock scrub; fr.

Ceropegia Randallii N.E. Br. Rock outcrops; occ. Shoots, Sept.; flowers, Dec. to Feb.; fruits and seeds, Jan. to Mar.

Pachycarpus schinzianus N.E. Br. Undisturbed veld; occ. Shoots, Sept.; flowers, Dec. to Feb.; fruits and seeds, Jan. to Mar.

Periglossum kassnerianum Chltr. Undisturbed veld; occ. Shoots, Sept.; flowers, Dec. to Feb.; fruits and seeds, Jan. to Mar.

Raphionacme divaricata Harv. Undisturbed veld; occ. Shoots. Sept.; flowers, Oct. to Dec.; fruits and seeds, Nov. to Feb.

Schizoglossum E. Mey.

Schizoglossum biflorum Schltr. Undisturbed veld; occ. Shoots, Sept.; flowers, Nov. to Feb.; fruits and seeds, Dec. to Mar.

Schizoglossum lamellatum Schltr. Undisturbed veld; occ. Shoots, Sept.; flowers, Nov. to Feb.; fruits and seeds, Dec. to Mar.

Xysmalobium undulatum R. Br. Watercourses; rare to occ. Shoots, Sept.; flowers, Dec. to Jan.; fruits and seeds, Jan. to Mar.

Convolvulaceae.

Ipomoca Linn.

Ipomoea bathicolpos Hall. f. Old termitaria; occ. to fr. Old roads; occ, to fr. Old ploughed lands: occ. Shoots, Sept.; flowers, Nov. to Mar.; fruits and seeds, Dec. to Apr.

Ipomoea crassipes Hook. Old termitaria; occ. Undisturbed veld; occ. Shoots, Sept.; flowers, Dec. to Jan.; fruits and seeds, Jan. to Mar.

Ipomoea simplex Thunb. Undisturbed veld; occ. Shoots, Sept.; flowers, Dec. to Jan.; fruits and seeds, Jan. to Feb.

Ipomoea 4 spp. Moist sites; occ. Rock outcrops; occ. to fr.

Boraginaceae.

Ehretia hottentotica Burch. Acacia scrub; occ. to fr. Rock scrub; occ.

Myosotis sylvatica Hoffm. Watercourses; occ. Shoots, Sept.; flowers, Dec. to Feb.; fruits and seeds, Jan. to Mar.

Verbenaceae.

Lantana rosea Rafinr. Rock scrub; occ. Acacia scrub; occ.

Lippia salvifolia. Rock scrub; occ.

Verbena officinalis Linn. Watercourses; occ. to fr. Old ploughed lands; occ. to ab. Shoots, Sept.; flowers, Nov. to Feb.; fruits and seeds, Dec. to Mar.

Labiateae.

Becium obovatum var. hians N.E. Br. Undisturbed veld; occ. Shoots, Sept.; flowers, Oct. to Mar.; fruits and seeds, Nov. to Apr.

Teucrium capense Thunb. Acacia scrub; occ. to loc. fr. Shoots, Sept.; flowers, Dec. to Feb.; fruits and seeds, Jan. to Mar.

Solanaceae.

Physalis minima Linn. Annual. Old ploughed lands; occ. to v. ab. Old termitaria; occ. to fr.

Solanum (Tourn.) Linn.

Solanum capense Linn. Old termitaria; fr. Shoots, Sept.; flowers, Oct. to Jan.; fruits and seeds, Dec. to Mar.

Solanum indicum Linn. Old termitaria; occ. Old ploughed lands; occ. to fr.

Solanum nigrum Linn. Old ploughed lands; occ. to fr. Rock outcrops; occ. Shoots, Sept.; flowers, Oct. to Dec.; fruits and seeds, Dec. to Mar.

Solanum sisymbrifolium. Watercourses; occ. Old roads; occ. Shoots, Sept.; flowers, Nov. to Feb.; fruits and seeds, Dec. to Mar.

Scrophulariaceae.

Bopusia scabra Presl. Undisturbed veld; occ. Flowers, Oct. to Feb.; fruits and seeds, Nov. to Mar.

Cycnium adonense E. Meyer. Parasite. Old termitara; occ. Shoots, Sept.; flowers, Jan.; fruits and seeds, Feb. to Mar.

Limosella aquatica Linn. Water holes and watercourses; occ. to v. ab.

Phyllopodium sp. Old ploughed lands or other disturbed sites. Shoots, Sept.; flowers, Dec. to Feb.; fruits and seeds, Jan. to Mar.

Rhampicarpa capensis. Watercourses; occ. to fr. Water holes; occ. Moist sites; occ. Shoots, Sept.; flowers, Nov. to Feb.; fruits and seeds, Jan. to Mar.

Sopubia cana Harv. Parasite. Moist sites.

Striga Lour.

Striga elegans. Root parasite. Undisturbed veld; occ. to ab. Old ploughed lands; occ. to ab. Shoots, Sept.; flowers, Dec. to Mar.; fruits and seeds, Jan. to Apr.

Striga 2 spp. Moist sites; loc. v. ab.

Sutera sp. Undisturbed veld, moist sites, occ.

Veronica sp. Water holes and watercourses; rare to occ.

Walafrida densiflora Rolfe. Old ploughed lands; fr. to ab. Old roads; fr. Shoots, Aug.; flowers, Oct. to Apr.; fruits and seeds, Nov. to June.

Lentibulariaceae.

Utricularia 2 spp. Moist sites; occ.

Acanthaceae.

Blepharis 2 spp. Undisturbed veld; occ.

Justicia anagalloides J. Anders. Wide range of habitat. Undisturbed veld; occ. to fr. Old termitaria; occ. to fr. Old ploughed lands; occ. to fr. Old roads; occ. Rock outcrops; occ. Moist sites; occ. to fr. Watercourses, occ. to fr.

Rubiaceae.

Anthospermum pumilum Sond. Undisturbed veld; occ.

Oldenlandia Linn.

Oldenlandia amatymbica (Hochst.) K. Schum. Old ploughed lands; occ. to v. ab. Old roads; occ. to fr. Undisturbed veld; occ. Shoots, Sept.; flowers, Sept. to Dec.; fruits and seeds, Oct. to Jan.

Oldenlandia caffra E. & Z. Old ploughed lands; occ. to ab. Old roads; occ. to ab. Shoots, Aug.; flowers, mid-Sept. to Nov.; fruits and seeds, Oct. to Dec.

Oldenlandia thymelifolia (Presl.) O. Kotze. Old roads; occ. Old ploughed lands; occ. to fr. Shoots, Sept.; flowers, Oct. to Feb.; fruits and seeds, Dec. to Mar.

Pachystigma pygmaea. Undisturbed veld, old roads, old ploughed lands; occ. to fr. Shoots, Sept.; flowers, Dec. to Jan.; fruits and seeds, Dec. to Mar.

Pentanisia variabilis Harv. Undisturbed veld; occ. to fr. Shoots, Sept.; flowers, Oct. to Feb.; fruits and seeds, Nov. to Mar.

Plectronia mundtiana (Ch. & Chl.) Pappe. Rock scrub; occ. to fr.

Pygmaeothamnus Zeyheri. Rock outcrops; loc. v. ab. Undisturbed veld; occ. to fr. Old roads; occ. to fr. Shoots, Sept.; flowers, Dec. to Jan.; fruits and seeds, Jan. to Mar.

Spermacocce dibrachiata. Old ploughed lands; occ. to v. ab. Old roads; occ. to fr.

Dipsacaceae.

Scabiosa anthemifolia E. & Z. Undisturbed veld; occ. to fr. Shoots, Sept.; flowers, Nov. to Mar.; fruits and seeds, Dec. to Apr.

Cucurbitaceae.

Coccinia sp. Acacia scrub; rare to occ.

Cucumis hirsutus Sond. Undisturbed veld; occ. Shoots, Sept.; flowers, Nov. to Dec.; fruits and seeds, Dec. to Apr.

Campanulaceae.

Lightfootia denticulata Sond. Undisturbed veld; rare to occ.

Lobelia rosulata S. Moore. Moist sites; occ. to v. ab. Old ploughed lands; occ. to v. ab. Old roads; occ. to v. ab Undisturbed veld; occ. to f. ab. Shoots, Aug; flowers, Aug. to Mar.; fruits and seeds, Sept. to Apr.

Lobelia decipiens Sond. Moist sites; occ. to v. ab. Shoots, Aug.; flowers, Aug. to Mar.; fruits and seeds, Sept. to Apr.

Wahlenbergia undulata A.D.C. Watercourses; occ. to fr. Moist sites; occ. Old roads; occ. to ab. Old ploughed lands; occ. to ab. Shoots, Aug.; flowers, Nov. to Feb.; fruits and seeds, Dec. to Apr.

Compositae.

Artemisia afra Jacq. Watercourses; occ. Acacia scrub; occ. to fr.

Athrixia elata Sond. Undisturbed veld; occ.

Aster harveyanus Min. Undisturbed veld; occ. to fr. Shoots, Sept.; flowers, Nov. to Mar.; fruits and seeds, Dec. to Apr.

Aster muricata Less. Old roads; occ. to fr. Old ploughed lands; occ. to fr. Undisturbed veld; occ. to fr. Shoots, Sept.; flowers, Oct. to Mar.; fruits and seeds, Nov. to Apr.

Berkheya radula (Harv.) O. Hoffm. Moist sites; occ. to fr. Watercourses; occ. to fr.

Berkheya subulata Harv. Undisturbed veld; occ. Rock outcrops; occ.

Brachylaena discolor D.C. Acacia scrub; rare to occ.

Callilepis leptophylla Harv. Undisturbed veld; occ. to loc. ab. Shoots, Aug.; flowers, Oct. to Nov.; fruits and seeds, Nov. to Dec.

Conyza 2 spp. Old ploughed lands; occ. to v. ab. Old roads; occ. to ab.

Denekia capensis Thunb. Watercourses; occ. to loc. ab. Shoots, Sept.; flowers, Nov. to Feb.; fruits and seeds, Dec. to Mar.

Dicoma anomala Sond. Undisturbed veld; occ. Shoots, Sept.; flowers, Dec. to Feb.; fruits and seeds, Jan. to Apr.

Dicoma Zeyheri Sond. Undisturbed veld; occ. Rock outcrops; occ. to fr. Shoots, Sept.; flowers, Dec. to Feb.; fruits and seeds, Jan. to Mar.

Dimorphotheca spectabilis Schltr. Undisturbed veld; occ. to fr. Old ploughed lands; occ. to ab. Shoots, Aug.; flowers, Sept. to Mar.; fruits and seeds, Oct. to Apr.

Gazania pygmaea Sond. Undisturbed veld; occ. to fr. Shoots, Aug.; flowers, Sept. to Mar.; fruits and seeds, Oct. to Apr.

Gerbera discolor Sond. Moist sites; occ. to loc. ab. Undisturbed veld; occ. Shoots, Aug.; flowers, Sept.; fruits and seeds, Oct. to Feb.

Gerbera piloselloides Cass. Undisturbed veld. Shoots, Sept.; flowers, Oct. to Jan.; fruits and seeds, Nov. to Mar.

Gnaphalium undulatum. Old ploughed lands; fr. to v. ab.

Haplocarpha scaposa Harv. Moist sites; fr. to v. ab. Shoots, Aug.

Helichrysum Baill.

Helichrysum argyrosphaerum D.C. Old ploughed lands; occ. to fr. Old roads; occ. Shoots, Aug.; flowers, Sept. to Mar.

Helichrysum aureonitens Sch. Bip. Moist sites; occ. to v. ab. Shoots, Aug.; flowers, Sept. to Mar.; fruits and seeds, Oct. to Apr.

Helichrysum caespititium Sond. Undisturbed veld; occ. Old ploughed lands; occ. Shoots, Aug.; flowers, Sept. to Mar.; fruits and seeds, Oct. to Apr.

Helichrysum callicomum Harv. Moist sites; occ. Old ploughed lands; occ. to fr. Old roads; occ. to fr.

Helichrysum declinatum Less. Old ploughed lands; occ. to ab.

Helichrysum leiopodium D.C. Moist sites; occ. to ab. Undisturbed veld; occ. Shoots, Sept.; flowers, Dec. to Feb.; fruits and seeds, Jan. to Mar.

Helichrysum nudifolium Less. Moist sites; occ. to ab. Undisturbed veld; occ. Shoots, Sept., flowers, Dec. to Feb.; fruits and seeds, Jan. to Mar.

Helichrysum oreophyllum Klatt. Undisturbed veld; loc. ab. Shoots, Sept.; flowers, Oct. to Feb.; fruits and seeds, Nov. to Mar.

Nidorella anomala Steetz. Moist sites and old roads; occ. to loc. v. ab. Old ploughed lands; occ. to v. ab. Shoots, Sept.; flowers, Nov. to Mar.; fruits and seeds, Dec. to Apr.

Nidorella hottentotica D.C. Moist sites, old roads, old ploughed lands; occ. to loc. ab. Shoots, Sept.; flowers, Nov. to Mar.; fruits and seeds, Dec. to Apr.

Nolletia rarifolia (Turez) Steetz. Undisturbed veld; rare.

Othonna natalensis Sel. Bip. Rock outcrops; rare.

Schistostephium crataegifolium Feusl. Moist sites; occ. to loc. v. ab.

Senecio Linn.

Senecio coronatus Harv. Undisturbed veld; fr. Shoots, Aug.; flowers, Oct. to Jan.; fruits and seeds, Nov. to Feb.

Senecio glanduliferus C. E. Moss. Undisturbed veld and moist sites; occ. to fr. Shoots, Aug.; flowers, Oct. to Feb.; fruits and seeds, Nov. to Mar.

Senecio isatideus D.C. Watercourses; occ. to loc. fr.

Senecio laevigatus Thunb. Old roads; occ. to ab. Old ploughed lands; occ. to v. ab. Old termitaria; occ. to fr. Shoots, July; flowers, Aug. to Apr.; fruits and seeds, Sept. to June.

Senecio mollicomus C. A. Smith. Undisturbed veld; rare.

Senecio pentactinus Klatt. Acacia scrub; loc. v. ab. Shoots, Sept.; flowers, Jan. to Mar.; fruits and seeds, Feb. to Apr.

Senecio serra Sond. Undisturbed veld and moist sites; occ. to ab. Shoots, Sept.; flowers, Dec. to Feb.; fruits and seeds, Feb. to Mar.

Senecio succosus C. E. Moss. Moist sites; fr. Undisturbed veld; occ. Shoots, Aug.; flowers, Oct. to Feb.; fruits and seeds, Nov. to Mar.

Senecio venosus Harv. Undisturbed veld; occ. to fr. Old ploughed lands; occ. to fr. Old roads; occ. to fr. Shoots, Sept.; flowers, Dec. to Feb.; fruits and seeds, Jan. to Mar.

Sonchus oleraceus Linn. Old roads; occ. Old ploughed lands, occ. to fr.

Sonchus capense. Undisturbed veld; rare to occ.

Stoebe vulgaris Levyns. Over trampled veld; occ. to v. ab. Old roads; occ. to ab.

Xanthium spinosum Linn. Old ploughed lands; occ. to v. ab. Old roads; occ. to ab. Watercourses; occ. to v. ab.

Xanthium strumarium Linn. Old ploughed lands; occ. to v. ab. Old roads; occ. to ab. Watercourses; occ. to v. ab.

Zinnia paucifolia Linn. Old ploughed lands; occ. to fr. Old roads; occ.

CONCLUSIONS.

1. Plants found on the highveld may be divided into three main types, e.g. (a) plants which adhere to one type of habitat only, e.g., *Andropogon amplectens* on moist sites, *Myrothamnus flabellifolia* on rocky sites, *Cynodon dactylon* on disturbed sites, and *Trachypogon plumosus* on undisturbed veld; (b) plants which grow profusely in one type of habitat but are unable to adapt themselves to a wide range of habitats, e.g., *Eragrostis chalcantha* really belongs to undisturbed veld, but it is also found on moist sites, and disturbed veld; (c) plants which do not adhere to any one type of habitat, e.g., *Justicia anagalloides* is found equally abundantly on disturbed sites, moist sites, and undisturbed veld.

2. Plants such as *Ipomoea* spp., *Raphionacme divaricata, Elephantorrhiza elephantina, Parinarium capense* and *Gnidia* spp., are very often the first plants to appear on disturbed sites, such as old roads, ploughed lands, and severely trampled sites, on account of their ability to shoot from underground tubers.

3. *Protea—Other Species Open Woodland* is found most abundantly on exposed sites, whereas other types of scrub are confined to areas with protective influences, such as dykes, rocky outcrops, and watercourses, or spend the early stages of their development under the protection of the Proteas themselves.

4. A knowledge of the plant relations, one to another, and to varying habitats is of great value to the ecologist; for it not only aids him to determine different types of veld and their probable histories, but also aids in determining growth forms due to habitat influences, and permanent strains.

5. Phenological observations have been proved to be of very great importance in the study and management of individual species as well as the community constituents of the veld, also they are important in the timing of the collection of pollen for the study of hay-fever and the collection of seeds for germination experiments.

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Authorities for specific names have been taken from *Index Kewensis*, and *Burtt Davy's Check List*.

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AN IMPROVED METHOD IN THE STUDY OF ROOT BISECTS

BY

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Read 6 July, 1937.

As quoted in the paper by Scott and Van Breda (1937), the study of root bisects in America has been shown to be of both scientific interest and practical value. Apart from the work of Murray and Glover (1934) and Scott and Van Breda (1937), very little has been published on the subject in this country. While the general procedure recommended by the pioneer American workers has been followed on the Worcester Veld Reserve, it has been found necessary to explore the possibility of improving the means whereby roots and rootlets are exposed prior to the actual charting and the equipment to be used.

Methods Employed by Earlier Workers.

(1) Hays (1889) working in Minnesota, obtained useful information on the development of the roots of *Zea maydis* by washing away the soil from the roots.

(2) King (1892), of Winconsin, utilised a method by which the roots were held in their natural position after the soil was washed away. This method consisted of isolating a prism of soil several feet long and one foot thick by digging trenches round it to a depth embracing the terminals of the penetrating roots. A cage of wire-netting was constructed round the prism, wires were run through the soil of the prism and the loose soil was taken off and replaced by a block of plaster of paris. Finally the loose soil was removed from the cage by means of a force water pump, the cross wires holding the roots in position. This method has been subjected to a great deal of criticism by later investigators. The method, apart from being exceedingly laborious and needing a great deal of water, has not proved very accurate, as very fine rootlets are washed away during the process.

(3) Weaver (1926) devised a new and more practical direct method by digging a trench with vertical walls about 8-12 in. from the base of the plants to be examined, no attention being given to the root system during the process. On completion of the excavation, the roots are uncovered from the walls of the

trench, commencing from the base of the plant, by means of sharp-pointed implements.

The method employed by the writer on the Worcester Veld Reserve is given below, and may be of use to those who are interested in making a study of the root systems of plants.

Equipment Necessary.

Before work is commenced, the following equipment should be obtained:—

(1) *Charting Frame.*—This is constructed by making a frame 12 ft. × 6 ft. from deal 2 in. × 1½ in., and strengthening the four shoulders with cross struts 12 in. long. Holes, ¼ in. in diameter and 6 in. apart, are drilled in one long and one short side of the frame. Bolts, ¼ in. in diameter and 3 in. long have the heads removed, and a small hole is drilled through the head end of each, sufficiently large for 16 gauge wire to be threaded. The bolts are inserted in the holes with the thread end and the nuts are attached on the outside of the frame. Sixteen gauge wire is inserted in the holes in the bolts and fastened, and the wires are drawn parallel across the frame and attached to the opposite side.

Should the wires become too slack when working with the frame, they can be tightened by screwing up the nuts. To add to the stability of the frame, an iron rod, ¼ in. in diameter, can be fitted across the middle to prevent the long sides from sagging.

(2) *Compressed Air Pump.*—Any good cylinder pressure spray pump with 12 feet of hose attached and a suitable nozzle will do.

(3) *Earth Wire Picks.*—These can be made from different gauges of steel fencing wire by cutting pieces approximately 9-15 in. long and looping one end to act as a handle and sharpening the other.

(4) *Miscellaneous.*—In addition to the above, the following equipment is necessary:—Flexible rule, drawing board, squared paper, cold chisel and hammer, hatchet with sharp edge, pick, shovel and spade, and, if fine rootlets are to be exposed for any length of time before being charted or mounted, a fly spray pump filled with French polish.

Procedure.

After the plant for study has been selected, a preliminary examination of the plant to a depth of a few inches to ascertain the distribution of the surface laterals is often helpful in determining on which side of the plant the bisect should be made. Then a trench is dug on the selected side approximately 12 in.

away from the base of the plant, and, except in the case of small plants with limited lateral spreads, the trench should be 13 ft. long and 3 ft. wide. This allows the charting frame to be lowered and hung on the working side of the trench. In the case of smaller plants, however, a trench 7 ft. long by 2½ ft. wide may suffice if the charting frame is lowered with the short side first. While excavating the trench little or no regard is paid to the roots encountered. When the excavation is complete, the work of uncovering the roots is commenced from the base of the plant working outwards until the terminals of the laterals are reached. Should the lateral spread exceed 12 ft., the trench will have to be lengthened accordingly. The penetrating roots, in the case of deep-rooted plants, are then followed up to the entire depth of penetration. Roots travelling away from the working surface are uncovered to a depth of 18 in. into the wall of the trench. The spot where the root is left in the wall of the trench is indicated on the chart by the letter O. Where roots travel to the working surface and are lost during the excavation of the trench, the spots are indicated on the chart by the letter X. When all the roots required are uncovered, the bottom of the trench is cleaned of all loose earth, the charting frame is lowered and hung up against the working face by driving two iron pegs under the top shoulders of the frame into the wall of the trench.

The roots are charted to scale through the 6 in. meshes on the frame. When it is intended to chart smaller portions than the whole trench at one time, the position of the frame on the peg should be marked so that the frame may be taken away and replaced accurately for further charting. After charting, the trench is dug 6 ft. deeper and the same procedure is followed.

In the study of very deep root systems under average soil conditions, as a safety measure, the trench has to be widened considerably from the surface and the walls allowed to taper down. Where it is not necessary to excavate deeper than 10-12 ft., the trench need not be widened at the surface, but the vertical walls should be well timbered.

Uncovering of the Root System.

In making a thorough bisect study of the root system of a plant, it is essential that the terminals of the rootlets be uncovered *in situ*, and there is no easy method by which this can be accomplished. The writer has gone to much trouble in trying out different methods of uncovering the roots. Methods used and given up after a fair trial are:—

(1) Filling the entire excavation with water and baling it out after a few days. (Van Breda.)

(2) Allowing water to trickle down the working side of the trench and picking the soil away carefully. (Van Breda.)

(3) Spraying the working surface with water. (Murray and Glover.)

(4) Uncovering the roots by working the soil away by means of sharp pointed instruments. (Weaver.)

The disadvantages of those methods are as follows:—

Method 1: Apart from water requirements and labour there are many other disadvantages, such as the possibility of the walls of the trench caving in and the loss of accurate data regarding moisture content when uncovering the roots.

Method 2: A more successful method than No. 1 in the actual uncovering of the roots, but water has to be led and continually baled out of the trench.

Method 3: The force of the water necessary to make the spray effective breaks up most of the smaller rootlets.

Method 4: Though there is much to commend this method, it is very doubtful whether it is possible to recover the very fine threadlike rootlets with their terminals in an average dry hard soil.

Compressed Air Method.

After the above methods had been abandoned, the use of compressed air was adopted. When the soil of the working face of the trench has been worked away with the bigger tools close to the roots to be uncovered, the wire picks are used to locate the roots. The larger roots are then uncovered by means of these, but where profuse fine branching is encountered the soil is pricked and the air pump is used to blow the soil away. When working with a friable loam, it is not necessary to prick the soil at all. It is most remarkable how the fine rootlets are preserved by this method in comparison with removing the soil entirely by means of fine pointed instruments. The writer knows no other method that results in such accuracy in uncovering fine threadlike rootlets. It is very effective in practically all types of soil except where the soil is thoroughly saturated.

Preservation of Hairlike Rootlets for Charting or Mounting.

With the majority of plants, hairlike roots dry up in a very short while and will stand no handling when exposed to the air. The writer has found that, if these rootlets are sprayed with French polish immediately on exposure, they are successfully preserved for charting and can be easily removed and mounted. When mounting, the selected rootlets are sprayed, removed from the soil while the polish is still damp and laid down on the mounting paper with the sprayed side against the paper and pressed.

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A METHOD OF CHARTING KARROO VEGETATION

BY

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With 1 Text Figure and 1 Chart.

Read 6 July, 1937.

Up to the present much attention has been paid to the various methods of charting and mapping grass veld in ecological work. The most commonly used methods were described, discussed and criticised by West (1). So far very little attention has been paid to charting karroid vegetation, though in a few cases where a vegetation survey of karroo areas under experiment has been necessary, the correct method of procedure has been much debated. After a trial of various methods, the following method has been adopted in mapping the communities for ecological studies on the Worcester Veld Reserve.

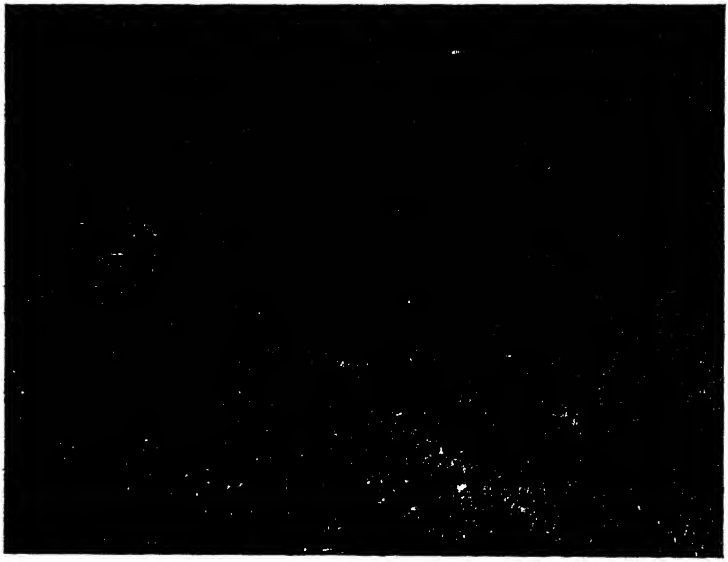
(a) Preliminary Studies.

In order to accustom the eye to estimate the cover and make up of cover in a given area, belt transects are first laid down in typical communities. The transects are charted to scale, the area actually covered by the branches and foliage of the plants, and not the basal parts of the plants as in the case of grasses, being charted. The percentage of the area actually covered is worked out and the percentage make-up of this cover is calculated. After a number of transects have been done, further transects are laid down, but the percentage cover and make up are first estimated and then checked up by charting. It is found that, within a very short time, an observer is able to estimate the cover and make up of that cover correctly.

(b) Charting of Large Experimental Areas.

After this preliminary survey, the area, if sufficiently large, is first pegged off into plots of approximately one morgen. The corners of the plots are pegged and permanently numbered. After the entire area to be worked has been divided up into these morgen plots, the whole area is sketched to scale showing the position of the plots and of the permanent corner pegs. Indicating the contours roughly on this key map helps considerably in locating the elevation and position of the plots especially in large hilly areas.

After this land survey has been completed the charting of the vegetation is commenced. Four temporary tall flags are placed, one at each corner of the plot, and, by means of a strong piece of garden twine measuring a third of the length of the side of the plot, the morgen plot is divided into nine small plots each approximately 34 × 34 yards. The corners of these small plots are temporarily marked. The observer then walks through the area and charts to scale any large bare areas and the positions of the various community types. Taking each community in turn in this small plot he first estimates the total vegetation cover in fractions of ten. The percentage of the actual cover of the individual species is then estimated, first the dominant and subdominant, and then the remaining species. Where the individual species are estimated at less than 1 per cent., the actual number of plants is counted and entered. On the actual map (see specimen), where the percentage is estimated the figures follow the exponent, where the number of plants is counted, the figure precedes the exponent (e.g., R.C.^{40}=*Ruschia carrli* 40 per cent. 3 R.I.=3 plants, *Rhus incisa*).



After completing the mapping of the small plot, the temporary flags are removed to the corners of the next small plot and the same procedure is followed. After mapping the entire morgen plot, photographs are taken to record any features of particular interest, and the spot from which the photograph was taken is permanently marked with a fixed arrow showing the exact direction in which the photograph was taken. That position is also shown on the chart. The colouring of the photographs adds considerably to their value in picking out the various communities.

Vegetation Map - Plot 13 - Approx 1 morg

<u>Key to Chart</u>: The dominant is indicated by hatching and also by symbols.

Figures preceding letters indicate the number of isolated plants.

Figures following letters indicate estimated percentage of plants distributed in section of plot.

The dominant and sub-dominant exponents are encircled with double lines.

Density of vegetation cover is indicated by fractions of ten.

Exponents;

CC = Chrysocoma tenuifolia
P = Pteronia paniculata
DP = Delosperma pageanum
AB = Specimen No 29
CT = Asparagus africanus
GA = Aridaria spec. No 124
M = Euphorbia Mauritanica
SH = Helichrysum spec. N 286
AM = Haworthia margaritifera
E = Euphorbia burmanni
L = Lycium
RC = Ruschia caroli
A = Pteronia incana
G = Galenia africana
CL = Crassula lycopodioides
MV = Specimen No 21
FE = Specimen No 24
GL = Urginea altissima
Sbu = Senecio burchelli

LC = Crassula spec No 20
K = Pentzia incana-forma
JS = Senecio corymbiferus
PC = Pteronia spec. No 240
AA = Atriplex albicans
EK = Eriocephalus umbellatus
ZY = Zygophyllum
CS = Atriplex semi-baccata
Z = Kleinia radicans
V = Mesembrianthemum haworthi
TF = Tetragonia fruticosa
KA = Sutherlandia frutescens
R = Elytropappus rhinocerotis
BC = Cotyledon spec. No 34
EG = Eriocephalus glaber
Ms = Massonia spec No 10
Cu = Crassula rupestris
FC = Specimen No 9
Indicates spot from which photograph was taken

Ob = Cotyledon orbiculata
Cr = Crassula spec. No 4
MS = Lightfootia albens
WA = Aridaria spec. No 36
AV = Crassula densiflora
EA = Thesium spec. No 114
A = Aloe microstigina No 2
RJ = Rhus incisa
Mic = Microloma tenuifolia
I = Indigofera patens
Cr = Crassula spec No 110
Pa = Panicum spec No 12
Hp = Hermannia pallens
Y = Caralluma mammillaris
TH = Tetragonia hirsuta
AR = Cotyledon paniculata
AD = Boldeckia spec No 115
Rh = Rhus spec No 118

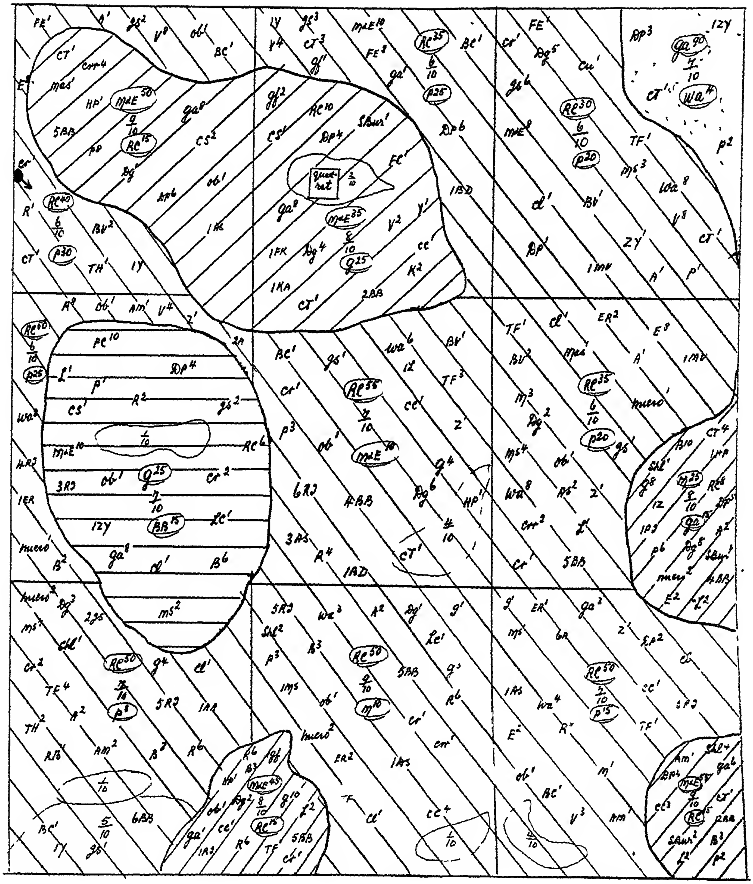
Hatching

Ruschia caroli

Galenia africana

Aridaria Spec No 146

Euphorbia Mauritanica & Brum.



To face Page 266

On the Worcester Veld Reserve the most convenient method of charting is to chart each morgen plot on a sheet 22 in. × 14 in. The map occupies an area of 14 in. × 14 in., while the rest of the sheet is used for a key to the chart and for mounting the relevant photograph. These maps are then bound together in book form, and can be taken out into the field when studying any particular features of the communities.

Discussion.

While the method may be criticised because it may allow a good deal of personal error, there is much to be said in favour of it. Small chart quadrats such as used in grass work are quite unsuitable as plants are widely spaced. Larger quadrats would be exceedingly laborious, and so many would be required over extensive karroo areas that it would be impracticable. Line transects would certainly give some indication of the make up of a vegetation, but would show very little as to the percentage of bare areas and percentage cover. This method, after the preliminary belt transects, can be done fairly quickly, and it shows up not only the cover and percentage make of the cover, but also the actual positions of the communities. The author is confident in stating that the average person, after a little preliminary work, will be consistently accurate in estimation of the cover and make up, and will be able to chart up to three plots of one morgen each in one day. It sometimes occurs that the total of the estimated percentages in a plot varies slightly above or below 100, but it is felt that the method is sufficiently accurate to trace up any appreciable changes in individual species as well as in communities and total cover.

Acknowledgments.

The writer wishes to thank the Chief of the Division of Plant Industry for his interest and support and for permission to publish this paper. He is also grateful to Mr. J. D. Scott, Pasture Research Officer, for suggestions and criticisms.

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South African Journal of Science, *Vol. XXXIV, pp. 268-274, November, 1937.*

PRELIMINARY STUDIES ON THE ROOT SYSTEM OF *GALENIA AFRICANA* ON THE WORCESTER VELD RESERVE

BY

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With 5 Text Figures.

Read 6 July, 1937.

Galenia africana (the Kraalbos) is one of the commonest and most widely spread species on the Worcester Veld Reserve. Not only is it found throughout the veld on the lower lying areas of the Reserve, but it is the first invader of disturbed areas. In continuation of the work on root studies of important plants of the Reserve (Scott and Van Breda, 1937), it was decided to study the root system of plants growing under various conditions to discover whether light would be thrown on success of the species as a coloniser under the different conditions.

Procedure.

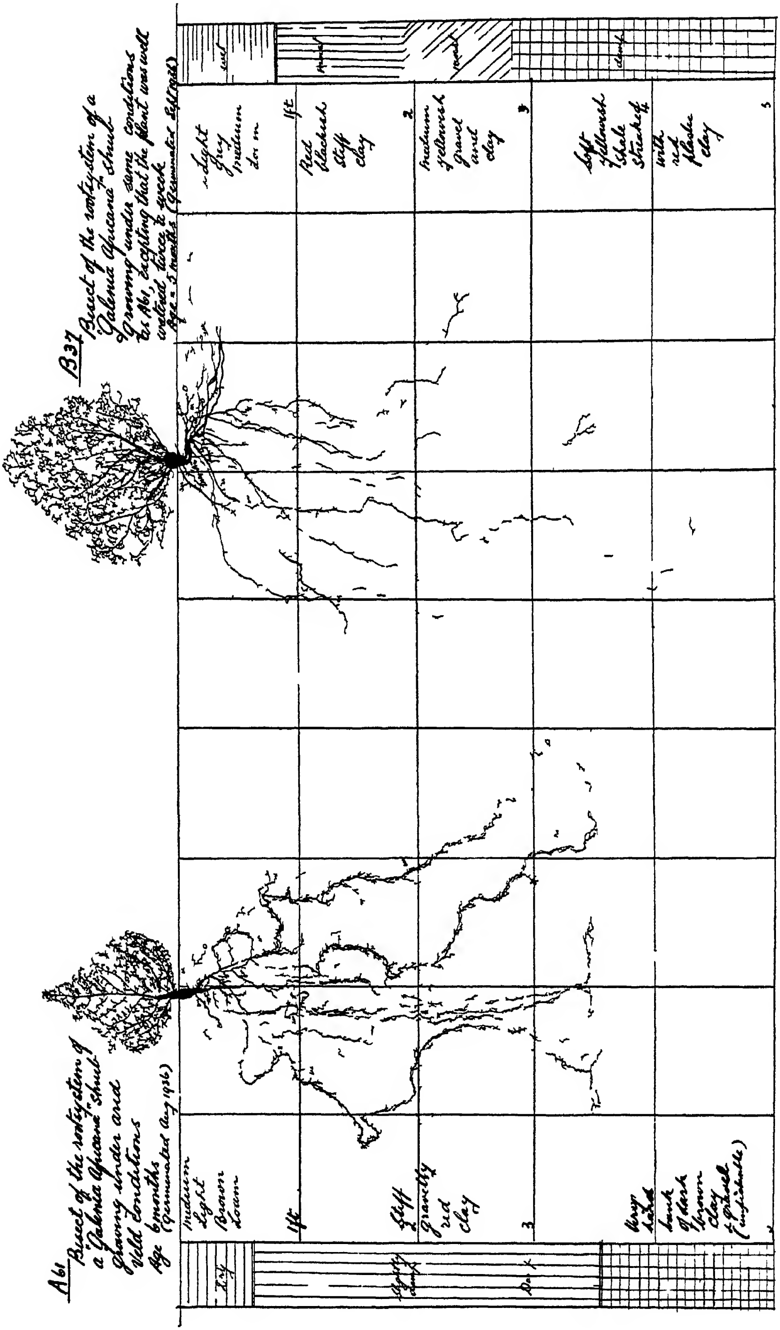
The same procedure in excavating the roots was followed as in the case of Renosterbos (Scott and Van Breda, 1937), except that a new method of using compressed air to uncover the roots instead of spraying or dripping water on the surface to be worked. The method is described elsewhere in this Journal.

Locality Plant Communities: Soil Type.

The Worcester Veld Reserve lies about three miles to the north-east of Worcester. Part of the Reserve consists of stony koppies and part of fairly flat land with poor soils derived from the Malmesbury clay slates. The studies were carried out on the flat land. The plant communities consisted of *Galenia africana, Ruschia multiflora, Pteronia paniculata, Euphorbia mauretanica, Pteronia incana* and *Elytropappus rhinocerotus.*

Results.

From a fair number of bisects made, four diagrams drawn to scale have been selected as typical of the plants growing under



Ref No B 37

Ref No A 61

the different conditions, and the following descriptions of the selected plants are made.

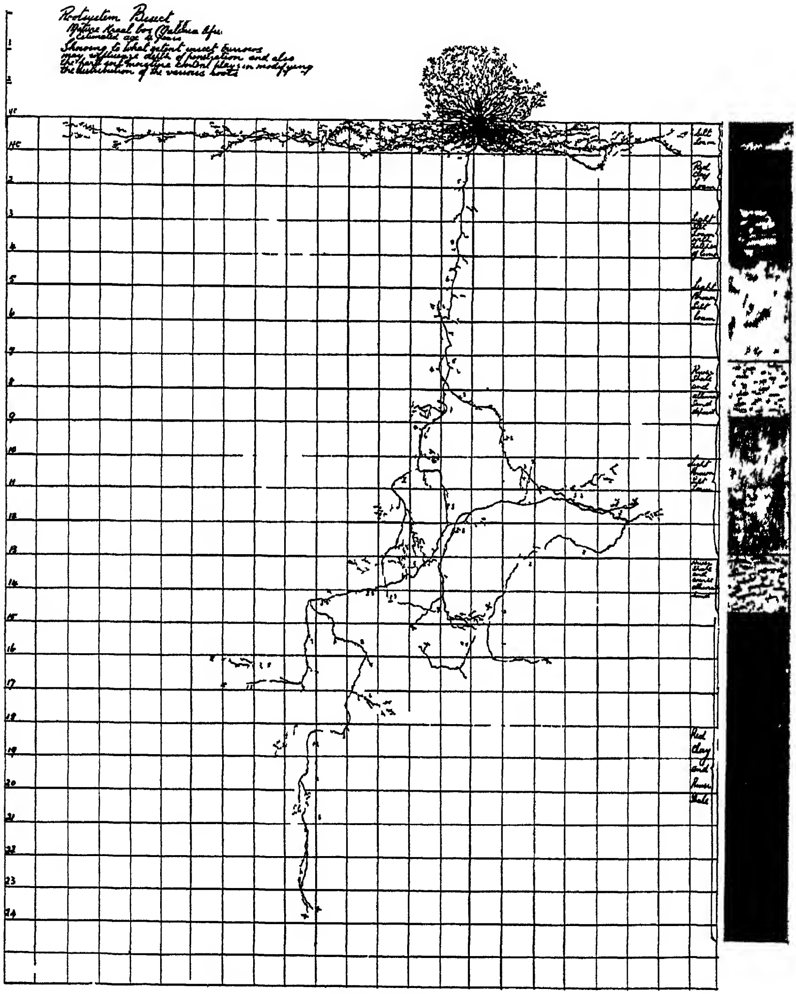
Two young plants growing under widely different conditions were studied. The first (A 61) germinated in August, 1936, and was growing under normal arid veld conditions. Work was begun in February, 1937. At the surface of the ground this plant measured 10 mm. in diameter. It formed a distinct tap root, and all the laterals grew down almost parallel with the tap root. Numerous fine rootlets ran together along the roots, forming a matted cluster. This was probably because the roots were following up the passage of decayed roots of a previous plant where the soil was less hard and dry. At 3 ft. 6 in. a very hard bank of dark clay and gravel was encountered, and here the roots branched and spread out horizontally.

The second plant (B 37) germinated in September, 1936, and was watered twice weekly. Apart from having no definite tap root the laterals spread out, and the roots were evenly distributed in all directions. The penetrating roots were much more frail than these in A 61, and there was no matted clusters of rootlets. Actually the roots penetrated to a greater depth than four feet, but no hard bank at lower depths was encountered. Had the soils been similar throughout, it is considered that the roots of the plant growing under the arid conditions would have penetrated to a much greater depth. A study of the diagrams shows that the branching of the roots both as to number and direction varies considerably with the moisture conditions of the soil.

The diagrams 2 B, 2 E and 2 I show bisects of three plants whose ages are estimated as from four to seven years. Nos. 2 B and 2 E were growing under normal arid veld conditions, while 2 I was located in a moist area caused through seepage from a water furrow. Here again considerable differences are noted in root development between plants growing under dry and moist conditions. In all cases, when plants have reached a certain age, the crown splits into a number of sections above and just below ground level, each section having a number of roots, but all the sections still fused at a point below the soil surface.

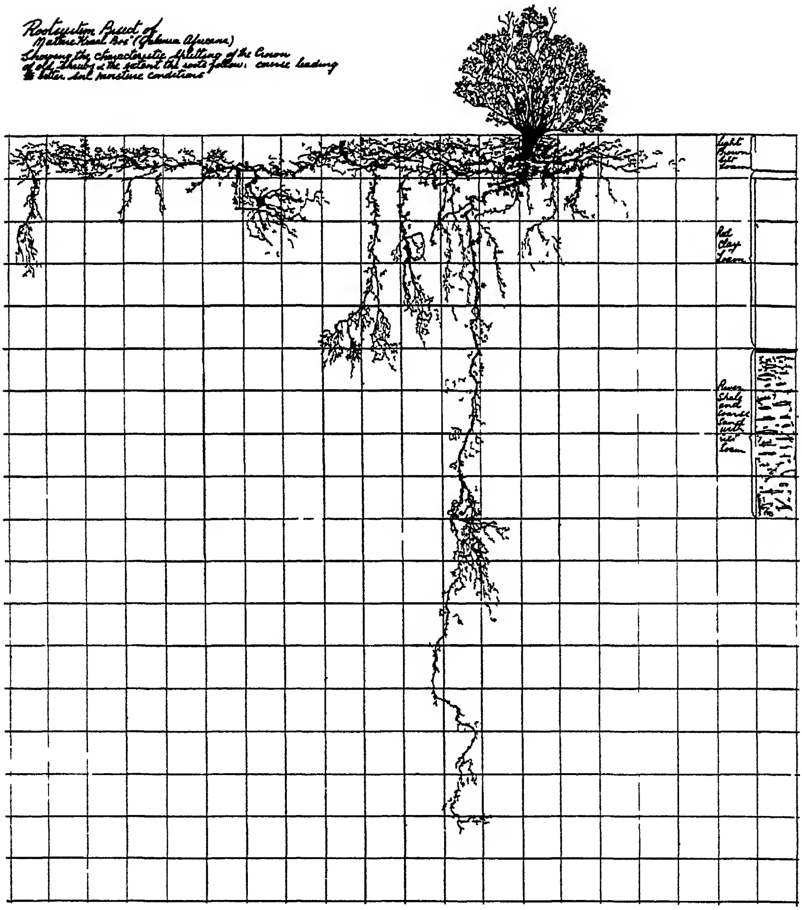
In No. 2 B the main root at the crown of the plant just below the surface measured approximately $2\frac{1}{2}$ inches in diameter, and although the root was solidly held together, three distinct sections were discernible. At a depth of eight inches all appearance of sections has disappeared, and the root had tapered to one inch in diameter, having already given off a number of surface laterals. All the surface laterals were given off within the first foot of soil, and consisted of ten major laterals ranging from $\frac{3}{8}$-$\frac{3}{4}$ inch in diameter, and numerous threadlike ones of 1/16 inch or less. These spread out horizontally to 7 to 13 feet from the plant and were covered, especially within the first two feet away from the plant, with dense clusters of hairlike roots. As the

laterals extended away from the plant they became more sparsely branched and only in certain places showed any clusters of fine hairs. The main root grew vertically for seven feet, entering an ant burrow and following it right down. Numerous fine roots were given off, but none spread outside the ant passages. Where these passages branched the rootlets followed the passages, even ascending at times, the fine rootlets given off all following the ant passages and growing parallel to the main branches. The roots were traced to a depth of 24 feet when the work was discontinued.



Ref. No. 2 B.

This plant was growing in a bare area 325 square yards in extent. After a soft rain of 2½ inches in 48 hours, the soil was moist to a depth of 12 inches or more near the base of the plant, but, seven feet away from it, the moisture had penetrated only 1½ inches. This would account for the dense mass of root hairs near the base of the plant and the compartively little branching as the laterals spread away from it. The moisture in the ant passages, together with the hardness of the surrounding soil, probably accounted for the roots growing entirely in these passages.

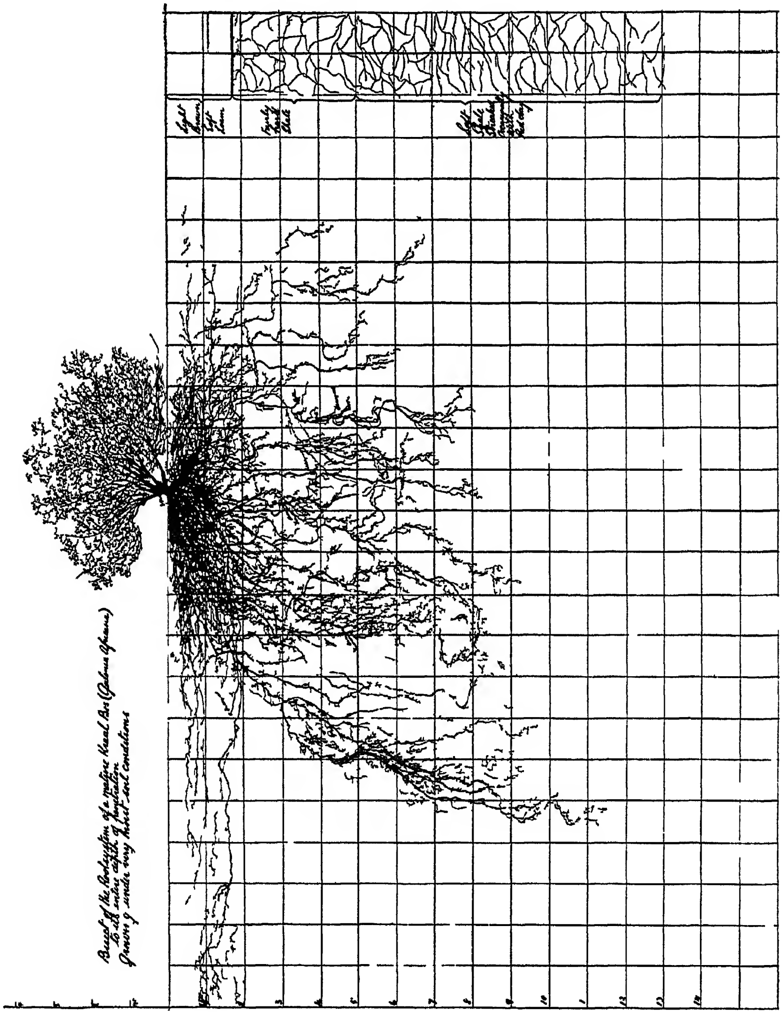


Ref. No. 2 E.

In No. 2 E the root measured three inches just below the soil surface and was in two sections, still fused. It also showed a dense network of fine hairs in the surface foot of soil, and then

one main root descending vertically to a depth of over 16 feet, and branching profusely at certain spots under more favourable soil and moisture conditions It is interesting to note that this plant was growing on the edge of a bare area In the bare area the lateral roots spread only to a distance of four feet, but in the opposite direction grew out to 14 feet The probable reason is because the bare baked area allows of little penetration of water, but where there was a dense stand of vegetation water could not run off as fast and so soaked into the soil and caused much more root growth

Figure 2 I shows a plant growing under moist soil conditions Here there was also a dividing of the crown with four main



Ref No. 2 I.

roots, fused just below the crown. The roots ramified throughout the soil in every direction. In the first two feet of soil to three feet on each side of the plant there was a dense network of fine hairs, but although there were far more branches in this plant throughout to its entire depth of 11 feet 6 inches, the tiny rootlets away from the plant were less branched and showed fewer dense clusters of hairs than the plants in the dry areas.

Discussion.

This preliminary study of the root systems of *Galenia africana* show that under various moisture conditions the roots develop quite differently. Under moist conditions there is profuse branching of the roots in every direction, but only around the plant are dense networks of fine hairs. No definite tap root is developed. Under dry conditions the plants show intense root development in the surface foot of soil with a dense network of hairs on all the rootlets. Definite tap roots are developed, and these penetrate to great depths, making use of ant burrows and passages left by decayed roots of other plants. Whenever soil moisture conditions improve there is intense development of root hairs. The success of this plant as a coloniser appears to be due to two causes, viz.: (1) The great root development of seedlings within a very short period (see diagrams A 61 and B 37), and (2) their development under different conditions to make the most of the moisture available. In the surface foot of soil there is tremendous root development to absorb any superficial moisture, and then there is a tap root descending to great depths and ramifying considerably whenever soil conditions are favourable. (1) Would account for its success as a coloniser, and (2) would supply the reason for its maintaining itself within communities of other plants.

Acknowledgments.

The writers wish to thank the Chief of the Division of Plant Industry for facilities for this work and for his continued interest therein.

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THE PRODUCTIVITY OF FERTILISED NATURAL HIGHVELD PASTURES

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TO

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With 3 Text Figures.

Read 6 July, 1937.

Introduction.

Although grassland research has been rapidly developing for some years, great difficulty is still being experienced by investigators when attempting to compare accurately the productivity of pasture plots receiving different treatments under controlled experimental conditions. The comparison of yields of agricultural crops, or yields of hay from a meadow where all that is produced in a season can be harvested at one time and measured in terms of pounds or tons per acre, can be made with reasonable accuracy; but the determination of the amount and quality of feed obtained by animals from a pasture presents to the investigator a very difficult problem.

Various methods of doing this have been employed, but each is liable to a certain degree of error. For instance, those involving the imitation of the grazing animal by cutting the herbage and measuring the yield at once bring in the error due to the difficulty of imitating exactly the selectivity of the animal. The recording of the number of cattle carried by a pasture for a given length of time, and expressing the results as grazing-day units, can also give misleading information on account of the variation in types of cattle, the difficulty of keeping an accurate check upon the effect of differently treated pasture plots upon their condition and gauging just when a plot has been grazed off sufficiently without being over- or under-grazed. Error can also creep in where small plots are grazed for fractions of a 24-hour period, for the variation in the grazing activity of animals throughout the day is considerable.

A further source of error, where grazing-day units are being used to compare the productivity of differently treated camps, is the retardation or acceleration of grazing caused by rotating one batch of cattle through a series of camps which, due to various fertiliser treatments, differ as regards palatability. It has been observed that animals graze rapidly when moved from a poor camp to a camp containing palatable grasses of high feeding value, and become replete with good grass in a short time. When they are again moved to a camp containing less palatable grasses of lower feeding value, they will remain for a considerable time without grazing avidly—thus causing some of the productivity of the former camp to be credited to the latter. The tendency is therefore towards a general levelling-up of grazing-day figures at the expense of the more highly productive camps. This lag is difficult to record, but the fact remains that it is not the length of time an animal stays in a camp that is so important as the quantity and quality of the herbage with which it can fill itself with the least expenditure of energy in a given time. From this aspect a camp will vary according to the season; in midsummer, a short period in the morning and afternoon may give the animal all that it requires and possibily more than it would obtain after a whole day's grazing in autumn. The variation in carrying capacity of differently treated camps is not, therefore, easily evaluated by these methods. In spite of such difficulties, however, comparative results can be obtained provided that the investigator uses more than one method—while being fully alive to the limitations of each. The evidence obtained from one method can then be substantiated or modified by that from another.

An attempt to work on these lines has been made in comparing the productivity of differently treated camps of a veld fertiliser experiment run jointly by African Explosives and Industries, Ltd., and the University of the Witwatersrand at Frankenwald, its Botanical Research Station. Other investigators have been collecting data upon the botanical composition of these camps and the physiology and phenology of the veld grasses in the experiment, but it is the object of this paper to study the production of herbage with regard to the amount and the quality of material provided for the grazing animal as influenced by various kinds and amounts of fertiliser.

Description of the Experiment.

The experiment just referred to has been fully described by Murray (5), and being similar in layout to the veld fertiliser experiments described by Hall (1 and 2) may be referred to very briefly here.

Eleven two-morgen camps, enclosing undisturbed highveld grassland as uniform as was possible to obtain, were fenced off and one of the following fertiliser treatments allotted to each:—

O, P, PN, PNK, PN_2K, PN_3K, Ca, PCa, PNCa, PNKCa, and OO. These symbols are interpreted as follows in lb. per morgen:

O = No fertiliser.
P = 400 lb. of equal quantities of super- and rock-phosphate.
N = 200 lb. of sulphate of ammonia.
K = 80 lb. of muriate of potash.
Ca = 2,000 lb. of carbonate of lime.
OO = No fertiliser and no grazing.

The fertilisers are applied annually in spring, except for the Ca which is applied every fifth year and the extra N dressings of the PN_2K and PN_3K camps which are applied at convenient intervals during the growing season. The OO camp is the only one not grazed.

The soil is a coarse grey sandy loam of pH 4·5-6·0. It is known to be deficient in phosphates and nitrogen, and appears also to be deficient in lime and potash. The subsoil is heavy and for the most part poorly drained, and the mother rock is grey granite. The veld is of a poor type from the grazier's point of view, and is known by farmers as the worst kind of sour veld. The experiment was laid out early in 1933, and the camps have subsequently been grazed in rotation for the duration of each growing season.

Procedure.

The standard method of comparing the productivity of the camps consisted of keeping accurate records of the amount of grazing yielded by each, the data being finally expressed in grazing-day units per morgen after the method described by Hall (2) and Vinall (7). Grazing records were kept for two full seasons after the 1932-33 season, and the summarised results which will be discussed later on are presented in Fig. 1. In calculating these results the sources of error already discussed were given due consideration where possible.

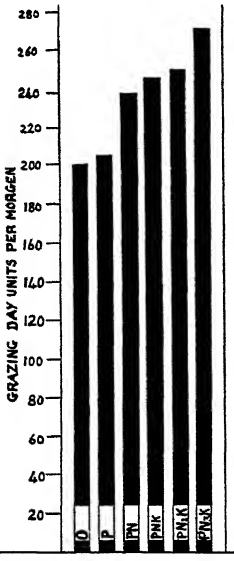
After this period of grazing it was decided to allow the camps to rest and reseed by locking them up for a complete growing period. It was therefore impossible to measure productivity by the grazing animal, so it was decided to compare the rate of growth and feeding value of the herbage by taking periodic sample cuts during the 1935-36 season. It was possible to take only five cuts at monthly intervals, the procedure being as follows:—Twenty-five 3 × 2 square yard areas were cut in each camp, the positions of which were randomised within certain areas selected both for their uniformity and similarity to one another. The randomisation of subsequent cuts was limited again to the portions of these areas unaffected by previous sampling. Each 3 × 2 square yard area was cut with a sickle to approximate grazing height, but no attempt was made to

imitate the selectivity of the animals by leaving some of the less palatable species uncut. The main reason for this was that it was almost impossible to gauge accurately the degree of selectivity that would have been shown by the cattle when grazing the differently treated plots. With this in view it was decided that a more accurate comparison of the plots could be made by cutting all the species comprising the sward and discarding only certain weeds that were known to be left ungrazed.

At each monthly cutting the whole series of eleven camps was sampled within two and a half days, so that any error due to increase growth of one camp over another was limited by this short period of time. The cut grass from each camp was then air-dried and weighed, and a sample taken for chemical analysis.

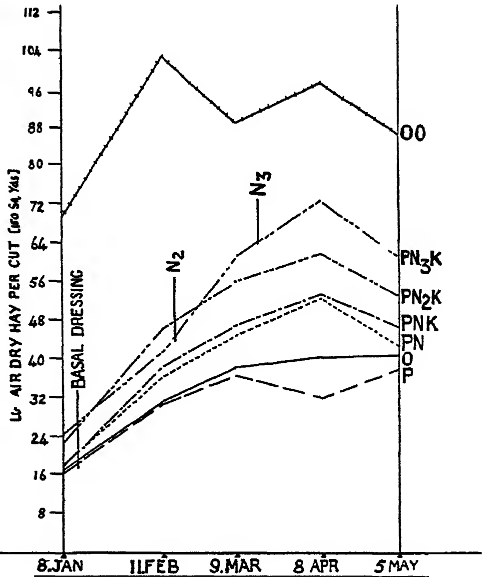
Before discussing the data obtained by these methods it should be mentioned here that, for simplicity, the eleven fertiliser treatments have been reduced to seven by regarding each Ca treated camp as a replication of that camp receiving the same treatment without Ca. Thus, the treatments referred to in this paper are O (= O + Ca) ; P (= P + PCa) ; PN (= PN + PNCa) ;

FIG 1



The effect of fertiliser treatment upon the average season's carrying capacity of veld pastures at Frankenwald based upon grazing records kept for two growing seasons.

FIG. 2



The effect of fertiliser treatment upon the seasonal growth of herbage of veld pastures at Frankenwald during the growing season of 1935-36. Dates of applications of fertilisers are indicated.

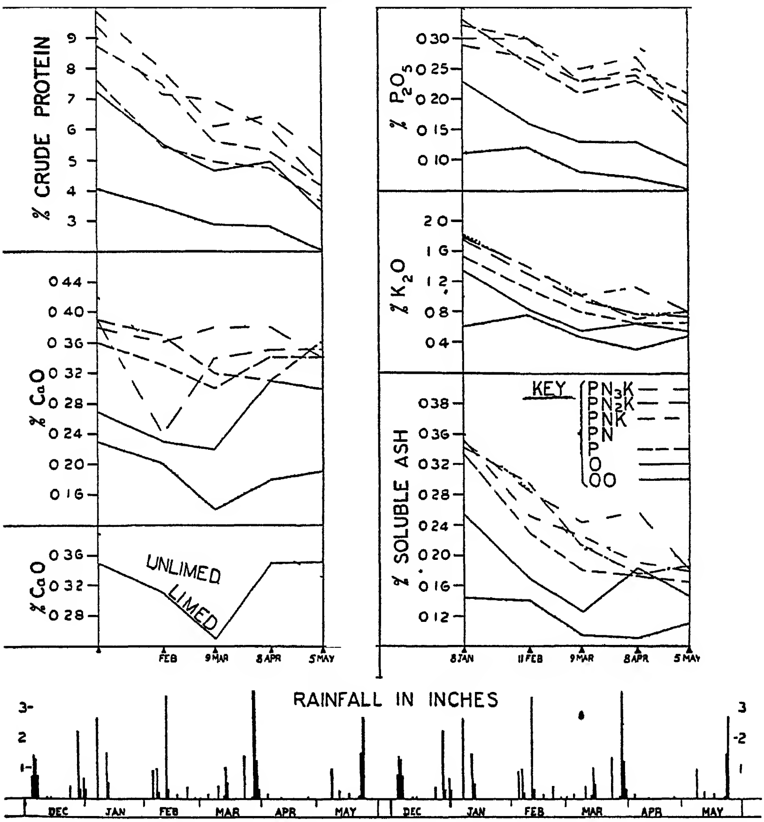
PNK (= PNK+PNKCa); PN_2K; PN_3K and OO. The effect of the Ca treatment is thus obscured, but this will be discussed separately. The original results obtained from each camp are shown in the appendix.

Discussion of Results.

Fig. 1 shows the average carrying capacity for one season in grazing-day units or "cow-days" per morgen for each treatment taken over the entire two-year grazing period, while the remaining Figs. 2 and 3 show the data from the productivity cuts taken during the season of rest. Fig. 2 shows the seasonal variation in the bulk of herbage from each treatment, while Fig. 3 shows the amounts of crude protein, P_2O_5, K_2O, CaO and

FIG 3 SEASONAL COMPOSITION OF HERBAGE

FRANKENWALD 1935-1936



The effect of fertiliser treatment upon the seasonal composition of herbage of veld pastures at Frankenwald during the growing season of 1935-36. Dates of applications of fertilisers are the same as those shown in Fig 2.

soluble ash present in this herbage expressed as percentages on a dry weight basis.

The results shown in Fig. 1 appear to fall into line with those of Hall and Meredith (4), which are based on thirteen similar experiments—the grazing records of which have been kept for four to six seasons. As these authors show, the most striking increase in carrying capacity is due to nitrogenous fertilisers when applied together with phosphates, but what is shown more clearly in Fig. 1 is the benefit from additional dressings of nitrogen during the growing season on the PN_2K and PN_3K camps. That the increases in carrying capacity are not great is true, but it must be borne in mind that the camps in question were enabled to maintain a comparatively high level of production towards the end of the season while the carrying capacity of the remaining camps was rapidly declining. This is a point of great importance to the practical farmer, whose chief problem is the extension of the very short season during which his veld is sufficiently productive to obviate the necessity for supplementary feeding. The increase in carrying capacity due to muriate of potash is small and may not be significant, but a similar increase is shown in the productivity cut data, which might have been more marked had the applications of the potash fertilisers been greater.

Not only does the graph in Fig. 2 bear out the differences in carrying capacity just discussed, but it also shows up some interesting details that might not otherwise have come to light. For instance, the January cut taken prior to the applications of the season's basal fertiliser dressings shows a marked residual effect from the previous season's treatment, and indicates that the most heavily fertilised camps have benefited from previous applications, even though they had been subjected to much heavier grazing than the less intensively fertilised areas. The accentuation of these yield differences by the subsequent basal dressings of fertilisers is shown by the remaining monthly cuts. The response to nitrogen in the presence of phosphate is clearly shown by every cut, and the benefit due to the extra dressings of nitrogen can readily be appreciated by studying the behaviour of the PN_2K and PN_3K curves in relation to the times of application which are indicated.

If the data from the April cut are taken as representative of the total yield per morgen from each treatment for the season, it will be seen how closely these figures correspond with the grazing-day units The only discrepancy is in the case of the "phosphate only" treatment, which shows a lower total production than the "no fertiliser" treatment, although it has a slightly higher carrying capacity. This is most likely due to the fact that the phosphate treated camps—being more palatable—were grazed more intensively than the unfertilised camps during the time the cattle were in them. As a result of this it is quite possible that the phosphate treated camps, when sampled during

the following season, were not able to produce such a high bulk of herbage as the control camps. The consistently lower content of P_2O_5, K_2O, CaO and soluble ash in the latter goes further to explain this discrepancy. The yield of herbage from the ungrazed control camp, which is the result of three seasons' accumulated growth, has been included in the graphs as a matter of interest. The high yield is to be expected, but it is interesting to note that the feeding value is considerably lower even than that of the unfertilised camps that are grazed.

A more accurate idea of the effect of the different fertiliser treatments upon the value of the herbage for animal production is obtained by studying Fig. 3 concurrently with Fig. 2. The crude protein content, as would be expected, is affected chiefly by nitrogenous fertilisers, and it is of interest to note how the extra topdressings which increased the total bulk and carrying capacity have also checked the usual rapid drop in protein content with the approach of the winter season. There appears, however, to be no increase due to phosphate without nitrogen, although the results of Hall and Moses (3) indicate this possibility.

With regard to the phosphoric oxide content, all camps treated with phosphatic fertilisers with or without the addition of nitrogen or potash show a definite increase in this constituent throughout the whole season. The very light dressings of muriate of potash do not appear to have had any significant effect upon the K_2O content of the grass, which, together with the CaO and soluble ash contents, appears to have been affected by fertilisers generally and to reflect again the value of dressings of nitrogen.

These results agree for the most part with those of other authors working along similar lines (3, 4 and 6), although Taylor in Natal (6) has not recorded such substantial increases in protein due to nitrogenous fertilisers.

The effect of agricultural lime upon the carrying capacity, chemical composition and bulk of herbage has been shown by comparing averages of the four limed camps with those of the four unlimed camps which receive otherwise similar treatment. The only results actually shown are those which give the CaO content of these two sets of camps, but the other chemical constituents discussed in this paper show up in much the same light—indicating that no benefits from liming are apparent and that there are signs even of a depressing effect. Beneficial results have, however, been recorded by other workers—(8) and Hall and Meredith (4) record increases in feeding value of herbage, while Taylor (6) shows definite increases in the CaO content of veld grasses of Natal when agricultural lime was included in the fertiliser dressings. As regards bulk of herbage and carrying capacity, the Ca camps have given higher yields, but the dressings have evidently been too light and insufficiently randomised to give any accurate information on the effect of this treatment.

In conclusion, attention must be drawn to the valuable additional data obtained from the taking of sample cuts from pastures and the manner in which it assists in interpreting their carrying capacity, which is normally expressed simply as grazing days.

SUMMARY.

(1) Attention is drawn to the difficulties of comparing accurately the carrying capacity of ten veld pasture camps that have been both unfertilised and fertilised in various ways, and alternative methods of obtaining such data were discussed.

(2) Data are presented showing the benefits to bulk, chemical composition and grazing days obtained by the application of fertilisers to various camps. Results as grazing days per morgen for two years are substantiated by seasonal yields from clippings taken the following year.

(3) The benefits to carrying capacity, seasonal yield and chemical composition from nitrogenous and phosphatic fertilisers are very evident, but phosphate alone did not increase the seasonal yields—due, it is thought, to heavier grazing brought about by its greater palatability as compared with the unfertilised camps.

(4) Extra dressings of nitrogenous fertilisers in the forms of sulphate of ammonia and nitro-chalk increased bulk, carrying capacity and protein content considerably, and three dressings appear to have maintained the potash, soluble ash contents and total bulk of herbage at a higher level at the close of the season.

(5) No direct benefit in chemical composition was recorded from either the use of lime or potash, although they did affect palatability, carrying capacity and total bulk of herbage. The opinion is expressed that heavier dressings of these materials might have given different results.

(6) The value of the additional information obtained from the periodic cuts taken from the camps and the agreement of the data so obtained with their carrying capacity are emphasised.

ACKNOWLEDGMENTS.

The authors wish to express their thanks to the Botany Department of the University of the Witwatersrand, on whose Research Station the pasture plots described in this paper are laid out; to Professor John Phillips, who. with the senior author, planned and laid out these plots; and also to Pretoria University for providing facilities for carrying out the chemical analyses of the grass samples.

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APPENDIX.

TABLE I.

Carrying capacity expressed in grazing-day units per morgen obtained from each camp in Series A at Frankenwald from the time of their layout in March, 1933, until the end of the 1934-35 growing season. Twenty units per morgen for each camp were obtained in March, 1933, and this amount has been added to the 1933-34 season's totals.

Camp No. and Treatment.	Season 1933-34.	Season 1934-35.	Average.
A. 1 P	179	146	163
2 PN	227	200	214
3 PNK	220	249	235
4 PN_2K	271	229	250
5 PN_3K	282	259	271
6 O	158	192	175
7 Ca	198	255	227
8 PCa	234	259	247
9 PNCa	233	289	261
10 PNKCa	262	251	257
11 OO (ungrazed) ...	—	—	—

TABLE II.

Air dry weights expressed in lb. of grass cut from twenty-five 3 × 2 yard areas in each camp at monthly intervals during the season 1935-36 on Series A at Frankenwald.

Camp No. and Treatment.	Jan.	Feb.	Mar.	Apl.	May.	Avge.
A. 1 P ...	14·6	23·0	35·5	28·0	32·5	26·7
2 PN ...	14·1	30·7	41·5	36·0	35·0	31·5
3 PNK ...	14·5	35·9	46·0	54·0	47·0	39·5
4 PN_2K ...	22·7	46·3	56·5	62·0	53·5	48·2
5 PN_3K ...	24·3	41·7	61·5	73·0	61·5	52·4
6 O ...	19·3	36·0	42·5	49·0	48·0	39·0
7 Ca ...	14·7	26·9	34·0	31·5	33·5	28·1
8 PCa ...	18·1	35·3	38·0	36·0	43·5	34·2
9 PNCa ...	21·4	42·6	49·0	69·5	50·5	46·6
10 PNKCa ...	20·1	41·8	49·0	53·0	46·0	42·0
11 OO ...	69·6	102·9	89·0	97·5	86·5	89·1

TABLE III.

Composition of grass samples collected from the productivity cuts taken at approximately monthly intervals during the season 1935-36 on Series A at Frankenwald.

CRUDE PROTEIN.

Camp No. and Treatment.			Jan.	Feb.	Mar.	Apl.	May.	Avge.
A.	1	P	7·83	5·25	5·25	4·71	3·46	5·30
	2	PN	9·54	6·30	4·91	4·88	3·90	5·91
	3	PNK	9·36	8·27	6·23	5·62	4·28	6·75
	4	PN_2K	9·41	7·16	6·95	6·04	4·24	6·76
	5	PN_3K	9·87	7·96	6·08	6·44	5·14	7·10
	6	O	7·54	5·52	4·69	5·13	3·51	5·28
	7	Ca	6·96	5·47	4·65	4·74	3·18	5·00
	8	PCa	7·41	5·57	4·67	4·76	3·82	5·25
	9	PNCa	8·47	6·61	5·66	5·15	3·74	5·93
	10	PNKCa	8·15	6·69	4·98	4·96	3·97	5·75
	11	OO	4·05	3·42	2·90	2·83	2·02	3·04

P_2O_5.

Camp No. and Treatment.			Jan.	Feb.	Mar.	Apl.	May.	Avge.
A.	1	P	0·35	0·28	0·21	0·26	0·21	0·26
	2	PN	0·42	0·31	0·27	0·29	0·28	0·31
	3	PNK	0·35	0·31	0 25	0·25	0·21	0·27
	4	PN_2K	0·30	0·30	0·25	0·27	0·17	0·26
	5	PN_3K	0·29	0·27	0·23	0·24	0·16	0·24
	6	O	0·23	0·15	0·12	0·12	0·08	0·14
	7	Ca	0·23	0·16	0·13	0·13	0·09	0·15
	8	PCa	0·31	0·23	0·20	0·20	0·16	0·22
	9	PNCa	0·28	0·29	0·21	0·28	0·20	0·25
	10	PNKCa	0·29	0·28	0·21	0·24	0·20	0·24
	11	OO	0·11	0·12	0·08	0·07	0·05	0·09

K_2O.

Camp No. and Treatment.			Jan.	Feb.	Mar.	Apl.	May.	Avge.
A.	1	P	1·54	1·24	1·04	0·62	0·63	1·01
	2	PN	1·88	1·52	1·16	0·67	0·73	1·19
	3	PNK	1·83	1·63	1·38	0·83	0·78	1·29
	4	PN_2K	1·76	1·30	0·95	0·76	0·74	1·10
	5	PN_3K	1·80	1·39	1·10	1·12	0·80	1·24
	6	O	1·35	0·80	0·54	0·77	0·55	0·80
	7	Ca	1·32	0·83	0·55	0·50	0·54	0·75
	8	PCa	1·51	0·95	0·54	0·66	0·66	0·86
	9	PNCa	1·74	1·36	0·80	0·84	0·83	1·11
	10	PNKCa	1·72	1·14	0·64	0·56	0·81	0·97
	11	OO	0·61	0·75	0·47	0·30	0·46	0·52

TABLE III—Continued.

CaO.

Camp No. and Treatment.			Jan.	Feb.	Mar.	Apl.	May.	Avge.
A.	1	P	0·41	0·35	0·35	0·35	0·35	0·30
	2	PN	0·44	0·35	0·37	0·47	0·40	0·41
	3	PNK	0·38	0·39	0·35	0·30	0·35	0·35
	4	PN_2K	0·39	0·24	0·34	0·35	0·35	0·33
	5	PN_3K	0·38	0·36	0·38	0·38	0·34	0·37
	6	O	0·24	0·22	0·20	0·28	0·25	0·24
	7	Ca	0·29	0·24	0·23	0·34	0·35	0·29
	8	PCa	0·30	0·30	0·24	0·33	0·32	0·30
	9	PNCa	0·40	0·34	0·24	0·41	0·36	0·35
	10	PNKCa	0·39	0·35	0·28	0·31	0·36	0·34
	11	OO	0·23	0·20	0·14	0·18	0·19	0·19

SOLUBLE ASH.

Camp No. and Treatment.			Jan.	Feb.	Mar.	Apl.	May.	Avge.
A.	1	P	3·82	2·59	2·29	1·82	1·70	2·44
	2	PN	3·84	3·05	2·46	2·07	1·86	2·66
	3	PNK	3·58	3·40	2·78	1·98	1·80	2·71
	4	PN_2K	3·53	2·51	2·24	1·91	1·78	2·39
	5	PN_3K	3·50	2·84	2·43	2·57	1·80	2·63
	6	O	2·52	1·67	1·22	1·92	1·35	1·74
	7	Ca	2·58	1·72	1·27	1·74	1·54	1·77
	8	PCa	2·85	1·98	1·31	1·69	1·72	1·91
	9	PNCa	3·37	2·67	1·70	2·16	2·01	2·38
	10	PNKCa	3·27	2·48	1·49	1·50	1·90	2·13
	11	OO	1·44	1·40	0·95	0·90	1·10	1·16

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LEAF-SCALD OF BARLEY IN SOUTH AFRICA

BY

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With 1 Text Figure.

Read 6 July, 1937.

The presence in South Africa of leaf-scald disease of barley has not hitherto been recorded, though it has been receiving considerable attention in America, Europe and Australia. My South African encounters with it have been in Cape districts ranging from Stellenbosch to north of Grahamstown. The importance of the disease is such that the most conspicuous symptoms associated with it in the Cape are described, so that other workers may recognise it. Apart from recording the disease in a country far from its known haunts, this paper adds something to the knowledge of the behaviour of the causal fungus, including items which are of interest to those who seek to control the disease.

Symptoms on the Leaf.—As the popular name implies, the leaf is the organ which shows the most conspicuous symptoms. The most typically affected leaves (see Fig. A) give the impression of having been spattered by biggish drops of some scalding or corroding liquid, the margin between the hurt tissues and the unhurt being marked by a conspicuous dark brown margin. The hurt tissue is bleached to a dirty-white colour, the " dirtiness " in the white being a light wash of ruddy, grey or brownish tint. The sizes attained by the blotches, as compared with the breadth of an average barley leaf, are shown in the illustration. Typical shapes of the blotches are also shown. The oval shape, as shown opposite the label (x) on Fig. A, is the commonest, or an oblong shape. By the " running together " of several neighbouring spots, the shape of the disease patch may become quite irregular, as shown at (y). When leaves bear such large spots, of such an unhealthy colour, they are conspicuous even at a distance. Especially by reason of the narrow decidedly dark margin they are also conspicuously different from leaves suffering from any other barley disease known to me. Decisiveness is, however, best attained by microscopic examination of spores, as mentioned below.

Under certain conditions, as at (w), the fungus may cause elongated lesions somewhat resembling those of leaf-stripe disease of barley (*Helminthosporium gramineum*). This elongated type of blotch is particularly liable to occur when it starts from an infection where, as shown in the figure, the auricles clasping

the stem, at the base of the leaf blade, make a kind of basin. This basin, collecting moisture and infective spores much more than the flat surfaces of the leaf, seems to be a starting point of infection in several barley diseases, including leaf-scald and leaf-stripe. Partly because the veins are fairly hard obstacles in the lower part of an expanded leaf blade, the fungi causing the two diseases are alike liable to pursue a path between the veins, making a long blotch bounded by parallel lines (veins), in other words a stripe. Nevertheless, in the case of leaf-scald the dark margin to the lighter inner zone is always to be distinguished, whereas in leaf-stripe disease the stripe is much more uniformly dark and uniformly *matt* (as if furry with microscopic hairs) in appearance.

It is further true that when the disease has just started to gain a hold, or, in its last stages, has effectually rotted most of the leaf, the symptoms may not be so obviously different from those of other leaf diseases. Since a great majority of infected crops, however, show different stages of the disease, including many of the easily-identified stages, not much need be said about the others. When an infection is very new only a small spot, looking more soaked with water than the rest of the leaf, is apparent. In Fig. A a rather new spot is indicated at (z). The broken-line shading on the leaf is meant to represent green colour, and this young blotch is represented as not having lost its green. Individual blotches seem to vary in regard to the speed with which the green colour in their centres disappears. At a rather late stage, considerable areas outside the brown margin of the blotch itself may become yellow and wither. The tissues of the " scalded " spot may ultimately be so rotted as to fall out.

The Causal Organism.

" Leaf-scald " is caused by a fungus, *Rhynchosporium secalis* (Oud.) Davis. In the blotched area hyphae are feeding on the mesophyll, and there later appear numerous hyphae running just underneath the epidermis and cuticle of the leaf. These parts of the mycelium begin to bud off the spores. A spore is shown in Fig. B.

Production of spores.—The mode of spore-production was observed when the fungus was growing on artificial media, where happenings such as shown in Fig. D occurred. For an account of what happens in the living parasitised barley leaf the account given by Brooks (1928: 216) may be referred to. It seems that, both under artificial cultures and on the barley leaves, the manner of spore production is simple. Short, somewhat claw-like, branches spring out from the main threads of the fungus, grow towards the open air (on the outside of the leaf or of the culture medium), take on a characteristic shape, and are easy to break off. From a diseased leaf the detached spores are easily shifted, by air-currents or by rain drops. Under suitable conditions they readily cause new infections, landing on healthy leaves or green chaffs.

The spores are easily moved owing to their small size. Spores collected in South Africa vary from 11·5 microns to 18 microns along their longest axis. Spores exceeding 17 microns are very uncommon, and the vast majority of those measured from the Cape Province measure between 12 and 16 microns. This agrees quite well with the measurements given for English localities, by Brooks, viz., 11-16. Rabenhorst (1903: 610) quotes 13-19 microns for spores from central Europe. The writer has collected spores in England as long as 20 microns.

Characteristic Shape of Spores.—As recorded by the above-mentioned and other authors the spores take on a highly characteristic shape (Fig. B). They are divided into two cells by a transverse wall. Whereas the proximal cell is comparatively narrow and nearly a symmetrical cone in shape, the other thicker cell is markedly asymmetrical, its curved end being canted conspicuously to one side. The Latin name of the fungus is apt, since by the constant presence of this beak the fungus can be identified more readily than by any other means. The other visible characters of the spores are not particularly helpful in distinguishing the fungus from others. The walls are colourless or slightly tinged with grey. Rarely there are *two* cross-walls instead of the usual *one.* At the thickest part the breadth is three to six microns.

In germination the spores send out a thread from one or both ends (Fig.C). Germination occurs readily on certain plants and also on a variety of nutrient jellies, e.g., mealie-meal agar. The fungus does not grow far over the surface of the jelly, but my somewhat limited experiments may not have shown me the best food. Spores produced in these artificial cultures are more clustered than Brooks (1928: 217) found them on barley leaves (Fig. D). I have not seen any other form of reproduction being manifested by this fungus, nor can I find that any other author has.

The Fungus on Wild Grasses.—In England I have infected species of *Agropyrum* with spores from barley, and *vice versa.* Though *Agropyrum* occurs in South Africa, I have not seen any infected with *Rhynchosporium.* The same holds true for other grasses on which, in England, I have seen the disease, e.g., species of *Bromus*, *Lolium italicum*, *Hordeum murinum*, and *Dactylis glomerata.* Nevertheless, from observations recorded in other countries, it is to be expected that the disease will be found on South African grasses. When a disease is easily transferable to wild grasses the control of the disease presents new problems.

In the United States of America, the breeding of immune varieties of barley has been shown by Mackie (1929: 1141) to be possible.

Transition from one Season to the next.—In the places, namely at Cambridge (England) and Albany in the Cape, where my investigations have been mainly carried out, it is easy to see

how the disease can persist from season to season. Living barley plants are to be found there all the year round. Bartels (1928: 73), in the more severe climate of Germany, found that the fungus was very resistant to freezing.

Infection of the Grain.—Occasionally conspicuous infection of the chaffs of barley grains has been observed (Fig. E). Such blotches, especially while the chaffs are still green, are in all essentials like those on the leaves. Other investigators, as far as I know, do not record an infection of the grain. The fungus has clearly a variety of aids to perennation, even if carriage by native grasses is excluded.

Even when there are no conspicuous blotches on the chaffs it seems that small infections or spores present on the grain have power to infect the new crop. Hauptfliesch (1929: 639), who apparently did not know that the establishment of a strong mycelium in the coats of the unripe grain occurs, yet found big reductions in the numbers of diseased seedlings by disinfecting the seed, e.g., with Uspulun.

South African Records.—The disease has been found at Stellenbosch, many times in Albany, and also the districts of Knysna, Humansdorp and Stockenstroom. In the last-named district some of the attacked fields were well above 4,000 feet above sea level, in marked contrast to the Knysna fields, which were near sea level, almost touching an estuary. While many plants are rendered ugly by the disease, there is no evidence to show that it causes very serious loss to the farmer. It has not been very serious under any of the conditions in which I have encountered it, but it is a disease well worth watching.

The disease also occurs in localities between South Africa and the well-known European infected regions. At Njoro in Kenya, C. A. Thorold collected the disease on barley. Dr. Nattrass collected specimens from Cyprus (No. 95, Cyprus Herbarium). I was responsible for the identification of these two collections.

Synonymy.—Both the disease and the causal fungus are sometimes referred to by names differing from those in this paper. The disease is sometimes called "leaf-blotch," but this seems undistinctive as compared with "leaf-scald." For the fungus I have used the name *Rhynchosporium secalis* (Oud.) Davis, but for a discussion of the nomenclature see Bartels (1928: 73, etc.) and Davis (1921: 413).

SUMMARY.

Leaf-scald of barley is recorded for the first time in South Africa from a number of Cape localities, providing different environmental conditions. The disease is common in Albany. Kenya cases are mentioned.

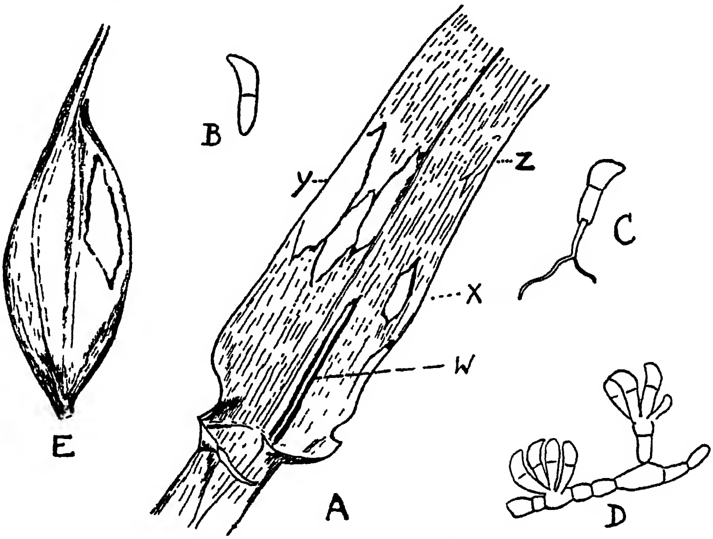
The disease does not cause any extremely serious damage in South Africa, though in some countries much energy has been spent on devising control measures.

The conspicuous symptoms are described and differences from other barley diseases pointed out.

The causal fungus is *Rhynchosporium secalis* (Oud.) Davis. Notes on the form and size of South African spores are given, showing a close agreement with spores from other lands. Notes are included on the mode of spore formation.

The disease was found often on wild grasses in England, but hitherto has only been seen on barley in South Africa.

The carrying of the disease from one season to another is discussed. The formation of blotches on the chaffs has not been recorded before.



EXPLANATION OF FIGURES.

A. Barley leaf showing different forms of scale blotches.
B. Spore of *Rhyncosporium.*
C. Germinating spore.
D. Mode of spore production from hypha grown in pure agar.
E. Grain with blotched chaff.

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POIKILOHYDRE PFLANZEN IN S.W. AFRIKA

von

Dr. G. Boss,

Swakopmund, S.W.A.

Mit 5 Abbildungen.

Am 6. Juli 1937 gelesen.

Das Tierreich wird in die zwei grossen Gruppen der " Warmbluetler " (homoitherme) und " Kaltbluetler " (poikilotherme) eingeteilt. Wie die "Kaltbluetler" ganz von der Temperatur der Aussenwelt abhaengig sind, so folgen auch viele Pflanzen voellig den Veraenderungen in " Wasserzustand " oder " Hydratur " ihrer Umgebung. Man hat deshalb diese Pflanzen in analoger Weise als " Poikilohydre " bezeichnet. Hierhin gehoeren Algen, Pilze, Flechten und Moose, deren Vertreter zum groessten Teil alle Schwankungen des Wasserzustandes der Aussenwelt mitmachen.

Von allen diesen Pflanzen weisen die Schimmelpilze das niedrigste " Hydraturminimum " auf, d.h. sie besitzen die beste Anpassung an unguenstige Wasserverhaeltnisse und vermoegen noch einen " Wasserzustand " zu ertragen, bei dem sonst keine andere Pflanze noch Lebensvorgaenge zeigen wuerde. Es ist deshalb kein Zufall, dass im trockenen Wuestengebiet der Namib ein Schimmelpilz *Aspergillus Welwitschiae* (Bres) P. Hennings auftritt. Dieser Pilz schmarotzt in den weiblichen Zapfen der *Welwitschie* und erfuellt sie mit einem schwarzen Pulver, das mit den Sporenmassen der Brandpilze (*Ustilagineen*) eine taeuschende Aehnlichkeit hat. In manchen Jahren findet man unter den *Welwitschien* kaum eine Pflanze, die nicht von diesem *Aspergillus* befallen waere. So weit das Verbreitungsgebiet der *Welwitschie* reicht, so weit ist auch der Pilz verbreitet. Ich habe ihn sowohl in Angola als auch im suedlichsten Vorkommen der *Welwitschie*, am Kuiseb, gefunden.

Alle uebrigen Pflanzen koennen nur bei hohen Hydraturgraden aktives Leben zeigen. Bei Abnahme des Wassergehaltes tritt sehr bald ein Aufhoeren aller Lebensvorgaenge ein. Beim allmaehlichen Austrocknen gehen die Pflanzen dann in den lufttrocknen Zustand ueber, trocknen also voellig aus. Die meisten Pilze, Flechten und Moose vertragen diesen Wasserverlust, ohne Schaden zu leiden. Sobald sie wieder Wasser aufnehmen koennen, setzen die Lebensvorgaenge von neuem ein, und die Pflanze beginnt ihr Wachstum an dem Punkte fortzu-

setzen, wo sie es beim Austrocknen einstellen musste (Poikilohydre Pflanzen).

Auch unter den Gefaesskryptogamen und selbst unter den Bluetenpflanzen gibt es eine ganze Reihe von Gewaechsen, die sich in ihrem Wasserhaushalt ebenso wie die Moose und Flechten verhalten. Sued West Afrika mit seinem extrem ariden Klima ist besonders reich an diesen interessanten Pflanzen; ueber den Wasserhaushalt dieser Gewaechse wissen wir aber bislang so gut wie nichts. Die spaerlichen Berichte der Fachliteratur begnuegen sich meist mit einem kurzen Hinweis auf das eigenartige Verhalten dieser Pflanzen. Aus der grossen Reihe der Untersuchungen, die ich im Laufe der letzten Jahre anstellte, sollen deshalb einige Ergebnisse hier vorgetragen werden.

Poikilohydre Gefaesskryptogamen.

Die Suedwester Farne gehoeren mit wenigen Ausnahmen zu der Gruppe der poikilohydren Pflanzen. Dem ariden Klima des Landes entspricht dieser Typus auch im vollkommensten Masse. Die meist kleinen Farne wachsen fast ausschliesslich im Schatten grosser Steinbloecke, die sie vor der unmittelbaren Einwirkung der Sonnenstrahlen schuetzen und ihnen so eine laengere Dauer ihrer Lebensfunktionen gewaehren. Aber selbst in der Regenzeit genuegt dieser Schutz nicht immer, vor allem dann nicht, wenn zich laengere regenlose Perioden einschieben. Dann schrumpfen die an und fuer sich schon kleinen Fiederblaettchen zusammen und rollen sich voellig ein; sie werden dann so trocken, dass man sie zwischen den Haenden zu Pulver zerreiben kann. Der naechste Regenguss gibt ihnen aber in wenigen Stunden das frische, gruene Aussehen zurueck. Diese Farne gehoeren den Gattungen *Cheilanthes*, *Ceterach*, *Actiniopteris*, *Notholaena* und *Pellaea* an.

Im Dezember 1935 und im Januar 1937 fuehrte ich im Waterberg mehrere Versuchsreihen mit den hier wachsenden haeufigen Farnen durch; es sind dies *Notholaena Eckloniana*, *Pellaea viridis* und *Ceterach cordatum*, var. *namaquensis*. Zunaechst bestimmte ich die Transpirationsgroesse dieser 3 Arten. Zu diesem Zwecke wurden die ausgewaehlten Versuchspflanzen mit der feuchten Erde sorgsam ausgegraben. Wurzel und anhaftende Erde wurden mit einem Gummiballon umgeben, dessen fester Ring den Wurzelhals eng umschliesst und so eine Wasserabgabe von Wurzeln und Erde verhindert. Um die Pflanzen moeglichst ohne Schaedigung in den Gummiballon einzufuehren, wurde das offene Ende ueber einen Serviettenring gezogen und nun Wurzeln mit anhaftender Erde eingefuehrt. Beim Abziehen des Serviettenrings schliesst sich der Gummiballon so dicht, dass Fehler, wie Kontrollversuche zeigten, sich praktisch nicht einstellten. Die so behandelten Pflanzen wurden nun an ihrem natuerlichen Standort samt dem Gummiballon wieder in die Erde eingegraben und alle 10 oder 15 minuten auf einer empfindlichen Waage abgewogen.

Die Verdunstungsgroesse wurde nur auf 1/100 Gramm genau bestimmt, hoehere Genauigkeiten sind ohne Bedeutung. Um diese Versuche mit anderen vergleichen zu koennen, die unter veraenderten Aussenbedingungen in Temperatur, Luftfeuchte, Windstaerke usw. durchgefuehrt wurden, stellte ich ein Piche-Evaporimeter neben die Versuchspflanzen. Das gruene Filtrierpapierblaettchen muss dabei immer in die Hoehe der transpirierenden Pflanzenteile gestellt werden; denn die Sonnenstrahlung, die unter dem Einfluss der Reflektion des Bodens ausserordentlich starken Veraenderungen ausgesetzt ist, gehoert zu den wichtigsten Faktoren, von denen die Transpirationsintensitaet abhaengig ist.

Die auf diese Weise erhaltenen Werte sind in den folgenden graphischen Darstellungen aufgezeichnet. Die Ordinate gibt den Wasserverlust an, der in gms ausgedrueckt ist. Auf der Abszisse sind die Versuchszeiten eingetragen, bei denen Gewichtsbestimmungen vorgenommen wurden. Die einzelnen Angaben sind durch gestrichelte Linien dargestellt, die ausgezogene Linie gibt die ausgeglichene Kurve an. Zum Vergleich sind jedesmal die Evaporimeter-Werte angegeben, allerdings nur im relativen Verhaeltnis (der Faktor ist immer angegeben), damit die zu vergleichenden Kurven nicht allzuweit auseinanderliegen.

Die Darstellung 1 (Abb. 1) zeigt den Ablauf der Transpiration bei dem Farn *Notholaena Eckloniana*. Die Waegungen wurden zunaechst im Abstand von 10 zu 10 Minuten von 13, 41 h—14, 31 h, von da an nur 1-stuendlich ausgefuehrt. Die

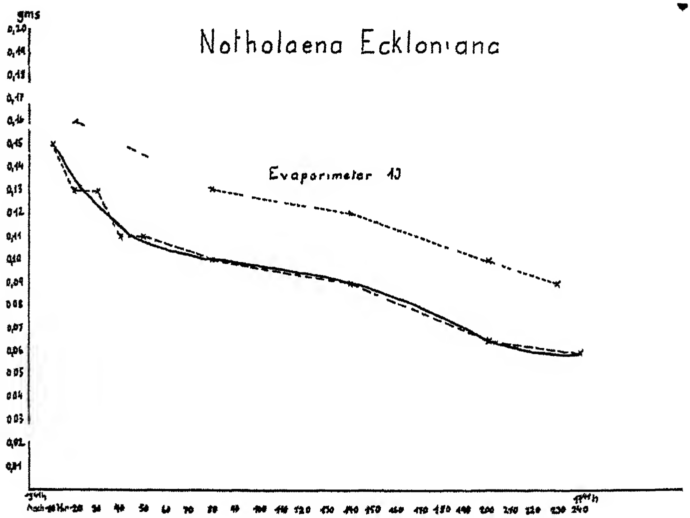

Abb. 1.

Ablauf der Transpiration bei *Notholaena Eckloniana*. Die gestrichelte Linie stellt die Verdunstung des Piche-Evaporimeters dar.

Versuche mit *Pellaea viridis* und mit *Ceterach cordatum* wurden zu gleicher Zeit durchgefuehrt. Die Kurven zeigen, dass die Transpirationsgroessen innerhalb der Versuchsfehler mit der Wasserabgabe des Piche-Evaporimeters parallel laufen.

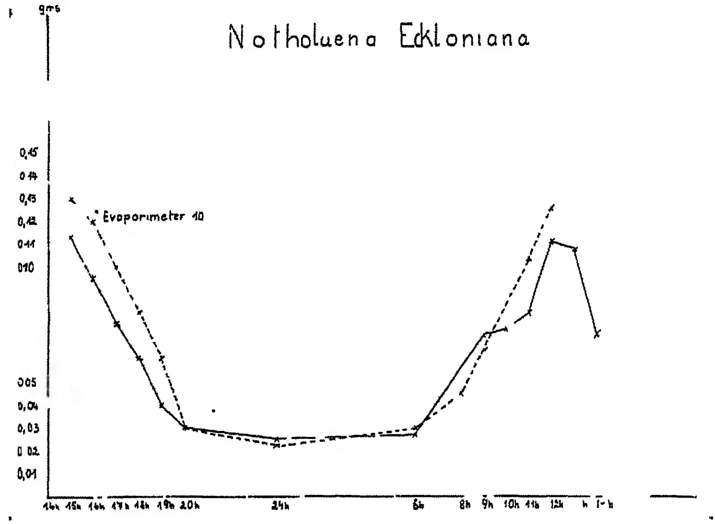

Abb. 2

Ablauf der Transpiration bei *Notholaena Ecklonana* während 24 Stunden.

Die Abbildungen (Abb. 2 und 3) geben den Ablauf der Transpiration bei den gleichen Pflanzen in Abstand von Stunde zu Stunde dar. Auch hier zeigt sich eine gute Uebereinstimmung mit den Werten des Evaporimeters. Bei 2 zeigt sich um 12 h des naechsten Tages und bei 3 um 11 h ein ploetzliches Absinken der Transpirationswerte.

Der Wassergehalt in der feuchten Erde des Gummiballons ist, soweit er fuer die Pflanzen verwertbar ist, erschoepft, und ohne einen allmaehlichen Uebergang fallen ganz abrupt die Transpirationswerte. Irgendwelche inneren Schutzeinrichtungen, die eine langsame Einschraenkung der Transpiration bedingen wuerden, scheint es nicht zu geben. Die aeusseren xeromorphen Merkmale wie relativ kleine Fiederblaettchen, Bedeckung mit Schuppen usw. ueben auch keinen Einfluss aus, ein Zeichen, wie wenig Wert man solchen aeusseren Merkmalen bei physiologischen Vorgaengen zuerkennen darf. Die aktiven Lebensvorgaenge hoeren fast mit dem Augenblick auf, wo keine voellige Wassersaettigung mehr vorliegt, ganz im Gegensatz zu den Bluetenpflanzen. Auch aeusserlich kommt dies durch das Einrollen der Fiederblaettchen zum Ausdruck. In Abb. 2 tritt um 12 h ein Einwaertskruemmen der Blattraender ein, um 13 h ist die Einrollung der Blaettchen schon sehr stark und erstreckt

sich ueber die ganze Pflanze; um 15 h ist das Gruen der Blaetter schon voellig verschwunden, nur die braune Farbe der Schuppen ist noch sichtbar.

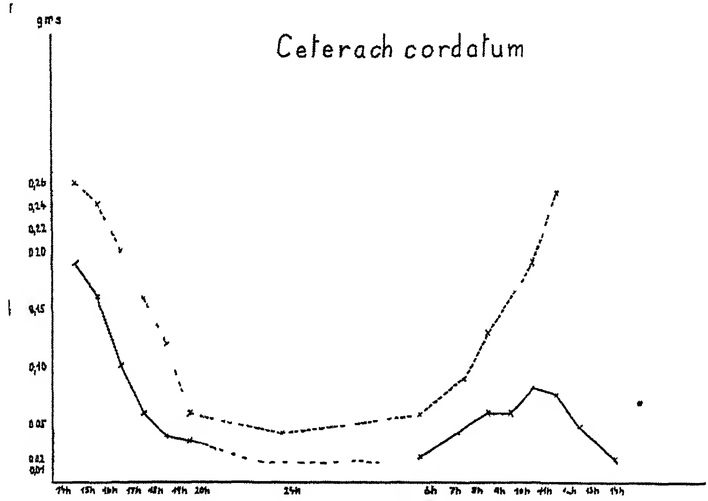

Abb. 3.
Verlauf der Transpiration bei *Ceterach cordatum*.

Um die Verdunstungsgroesse in einer Minute auf 1 gm Frischgewicht zu berechnen, wurden sodann die Pflanzen aus den Gummihuellen herausgenommen, die anhaftende Erde sorgfaeltig abgespuelt und sodann fuer 2 Stunden in Wasser gelegt. Die nun wieder voll mit Wasser gesaettigten Farne wurden alsdann an die Luft gelegt, bis die Oberflaeche ganz abgetrocknet war. Das so erhaltene Frischgewicht betrug

im 1. Fall 6,157 g
im 2. Fall 5,120 g
und im 3. Fall 1,541 g.

Die um 14 h ermittelte Verdunstungsgroesse fuer 10 Minuten wurde dann fuer eine Minute und fuer 1 g Frischgewicht ausgerechnet:

1. 1,96 mg. 2. 1,56 mg und 1,36 mg.

Die drei Arten wiesen also trotz ihres verschiedenen Baues keine allzugrossen Unterschiede in der Transpirationsgroesse auf. Die osmotischen Werte der Farne im aktiven Lebenszustand sind auch nur gering. Zur Bestimmung des osmotischen Wertes wurde die kryoskopische Methode benutzt. Es ergab sich fuer *Notholaena* ein Wert von 17,80 Atmosphaeren und fuer *Pellaea* 15,04 at. Diese Werte stimmen mit den Angaben, die H. Walter fuer verwandte nordamerikanische Arten macht, gut ueberein. Es scheint so, als ob die osmotischen Werte aller poikilohydren Farne in einem bestimmten Groessenbereich liegen.

Nun blieb noch ueber, das Verhalten dieser Farne beim voelligen Austrocknen zu verfolgen. Zu diesem Zwecke wurden die Versuchspflanzen sorgfaeltig von Erde befreit und dann in die Gummiballons eingefuehrt Die erhaltenen Werte sind in der folgenden Tabelle aufgefuehrt und in Abb. 4 graphisch dargestellt:

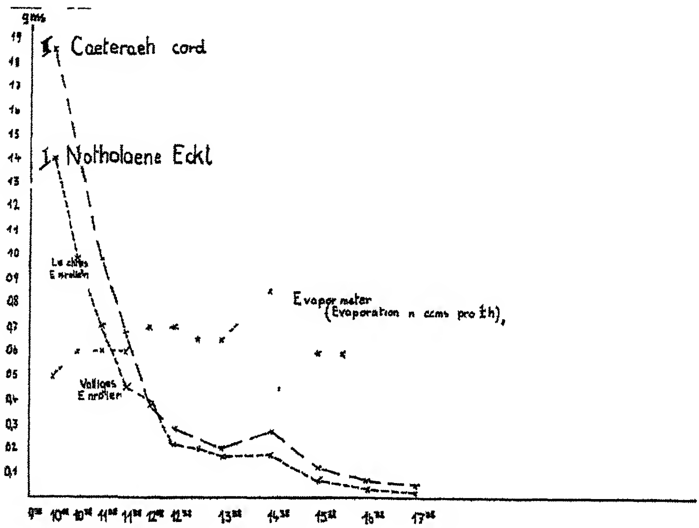

Abb. 4.

Verhalten von *Notholaena Ecklonıana* und *Ceterach cordatum* beim volligen Austrocknen Die Verdunstungsgrossen des Piche-Evaporimeters sınd in um fur je eine halbe Stunde ausgedruckt.

Zeit h.		*Notholaena Ecklonıana.* Gewicht der Pflanze. gms.	Transp. gms.		*Ceterach cordatum var. namaquensıs.* Gewicht der Pflanze. gms.	Transp. gms.
9^{38}	...	13,15	—	..	13,87	—
10^{08}	...	11,76	1,39	...	12,02	1,85
10^{38}	...	10,78	0,98	...	10,60	1,42
11^{08}	...	10,07	0,71	...	9,67	0,93
11^{38}	...	9,53	0,46	...	9,00	0,67
12^{08}	...	9,24	0,39	...	8,64	0,36
12^{38}	...	9,02	0,22	...	8,35	0,29
13^{38}	...	8,70	0,32	...	7,95	0,40
14^{38}	.	8,35	0,35	...	7,43	0,52
15^{38}	...	8,20	0,15	...	7,20	0,23
16^{38}	...	8,13	0,07	...	7,06	0,14
17^{38}	...	8,11	0,02	...	7,01	0,05

Das nochmalige Ansteigen der Wasserabgabe zwischen 13^{38} h und 14^{38} h zeigt, dass selbst bei diesem hochgradigen Wasserverlust die Witterungsfaktoren doch noch einen Einfluss ausueben. Die Kurve des Piche-Evaporimeters, das die Evaporation in ccms pro ½ h angibt, weist den Einfluss der Beschattung durch eine dicke Wolkendecke, die vor die Sonne trat, deutlich auf, ebenso den Anstieg der Evaporation durch erneutes Hervortreten der Sonne.

Ganz aehnlich verhaelt sich *Pellaea hastata*, auch hier wird der Wasserverlust ganz allmaehlich geringer, bis um 18^{30} h schon Lufttrockenheit eingetreten ist. Jedenfalls nahm das Gewicht in der Abendkuehle zu, ein Zeichen, dass die Pflanze in diesem Zustand voellige Lufttrockenheit erreicht hatte, sonst wuerde sie den Schwankungen der Luftfeuchte nicht folgen.

Pellaea hastata.

Zeit.		Gewicht der Pflanze.	Transpiration.	Evaporimeter.
h.			gms.	ccms.
12^{00}	...	27,12		
			0,74	0,9
12^{30}	...	26,38		
			0,45	0,7
13^{00}	...	25,93		
			0,43	0,8
13^{30}	...	25,50		
			0,31	0,7
14^{00}	...	25,19		
			0,19	0,6
14^{30}	...	25,00		
			0,22	0,8
15^{00}	...	24,78		
			0,24	1,1
15^{30}	...	24,54		
			0,18	0,6
16^{00}	...	24,36		
			0,18	0,7
16^{30}	...	24.18		
			0,14	0,6
17^{00}	...	24,04		
			0,12	0,6
17^{30}	...	23,92		
			0,07	0,6
18^{00}	...	23,83		
			0,06	0,4
18^{30}	...	23,77		

Bei *Pellaea hastata* war noch etwas Erde an den Wurzeln belassen worden, um festzustellen, ob dadurch ein bestimmter Einfluss auf die Geschwindigkeit Wasserverlustes festgestellt werden koennte. Auch hier zeigt sich wieder, wie ein Anwachsen der Verdunstung des Evaporimeters von einem groesseren Wasserverlust der Pflanze begleitet wird.

Nun galt es noch festzustellen, ob ein Farn beim Austrocknen und spaeteren Wiederergruenen sich verschieden verhalten

wuerde. Zu diesem Zwecke wurde die *Notholaena*-Pflanze wieder der Austrocknung unterworfen, und dabei die folgenden Zahlen festgestellt:

Zeit.	Gewicht der Pflanze.	Transpiration.	Trans-pro. 1 Minute.
h.		gms.	mgms.
11^{50}	10,04		
		0,99	49
12^{10}	9,05		
		1,74	28
13^{12}	7,31		
		0,74	6,4
15^{07}	6,57		
		0,76	3,1
19^{15}	5,81		
Nächster Tag		0,45	—
9^{10}	5,36		
		0,19	—
12^{10}	5,77		
		0,20	—
14^{10}	4,97		

Um 14^{10} h des naechsten Tages wurde die Pflanze in ein Zimmer gelegt, das 43% Luftfeuchte aufwies, waehrend im Freien die relative Luftfeuchte nur 28% betrug. Nach einstuendigem Verweilen im Zimmer wog die Pflanze 5,17 g, hatte also um 0,20 g zugenommen. Um 16 h setzte Regen ein, der Farn wurde wieder ins Freie gesetzt und von den Regentropfen voellig durchnaesst. Am naechsten Morgen war die Pflanze wieder voellig abgetrocknet, aber zeigte noch ein frisches gruenes Aussehen. Nun wurde sie wieder ins Freie gesetzt und der allmaehlichen Austrocknung wieder unterworfen. Die erhaltenen Werte sind unten dargestellt:

Zeit.	Gewicht der Pflanze.	Transpiration.	Trans-pro. 1 Minute.
h.		gms.	mgms.
9^{30}	10,92		
		0,61	40,7
9^{45}	10,31		
		1,94	22
11^{15}	8,32		
		0,23	7,7
11^{45}	8,09		
		0,12	8,0
12^{00}	7,97		
		0,60	3,3
15^{00}	6,57		
		0,60	—
17^{30}	5,97		
		0,15	—
19^{30}	5,82		
Nächster Tag		0,19	—
9^{30}	5,73		
		0,20	—
13^{00}	5,53		

Um die Werte vergleichen zu koennen, wurde der Wasserverlust in mg. pro 1 Minute umgerechnet. Die so erhaltenen Zahlen zeigen, dass keinerlei Veraenderung eingetreten ist. Dass die Werte bei der zweiten Versuchsreihe absolut abweichen, liegt eben an den Versuchsbedingungen: Die erste Versuchsreihe liegt in den heissen Mittagsstunden, die zweite wurde 2 Stunden frueher in dem etwas kuehleren Vormittag durchgefuehrt.

Poikilohydre Bluetenpflanzen.

Bis vor kurzem waren ueberhaupt keine Bluetenpflanzen bekannt, die voelliges Austrocknen vertragen. Der " Buschtee," *Myrothamnus flabellifolia* war die erste Art, bei der man diese Eigenschaft feststellte. Spaeter entdeckte man noch eine *Gesneracee* und eine *Carex*-Art, die als poikilohydre Pflanzen angesehen werden duerfen. In Wirklichkeit muss die Zahl der Bluetenpflanzen, die lufttrocken werden koennen, ohne dabei ihre Lebensfaehigkeit zu verlieren, wesentlich groesser sein. In Suedwest kommen allein ausser dem Buschtee noch 5 verschiedene Pflanzen hinzu, denen diese Eigenschaft zukommt. Es sind dies *Barbacenia* (*Vellozia*) *hereroensis* Schz., *Barbacenia minuta* (Bak) Otr., noch 2 seltenere *Barbacenia*-Arten und schliesslich die huebsche *Craterostigma plantagineum* Hochst. Aus dem Hochland von Huilla in Angola brachte ich im vergangenen Jahr noch zwei stambildende *Vellozia*-Arten mit, die gleichfalls den lufttrocknen Zustand ohne Schaden zu ertragen vermoegen.

Mit allen diesen Pflanzen fuehrte ich nun im Jahre 1936 ausgedehnte Versuche durch. Das dabei erhaltene umfangreiche Zahlenmaterial eignet sich nicht zu einem oeffentlichen Vortrag, wird aber noch im Laufe dieses Jahres an anderer Stelle veroeffentlicht werden.

Das Verbreitungsgebiet des Buschtees reicht weit in die Namib hinein, wo er bei Klein-Spitzkoppje und der Sphinx noch recht haeufig vorkommt. Bei Sphinx waren in den Jahren 1931 und 1932 kaum 20 mm. Regen gefallen. Und trotzdem ergruenten die staubtrocknen Blaetter wenige Stunden nach dem ersten Regen, und die Buesche standen in prachtvollem Gruen da.

Noch viel naeher an der Kueste, in einer Entfernung von nur 40 mcs., kommt *Barbacenia hereroensis* vor. Wie der Buschtee waechst auch diese Pflanze fast ausschliesslich in Granitspalten. Das ueberaus stark ausgebildete Wurzelsystem erlaubt der Pflanze, das von den glatten Granitfelsen abfliessende Wasser begierig aufzusaugen. Aber auch die Blaetter sind in der Lage, Wasser aufzunehmen: Pflanzen, denen die Wurzel abgeschnitten wurde, und die umgekehrt, also nur mit ihren Blaettern, in Wasser gestellt wurden, ergruenten in gleicher Weise wie vollstaendig intakte Gewaechse.

Wesentlich kleiner als *Barbacenia hereroensis* ist *Barbacenia minuta*. Die kleinen Pflaenzchen sind mit Hilfe von Plastilin in einer Porzellanschale eingesetzt worden. Der Unterschied

zwischen der trockenen und der wieder zu aktivem Leben erwachten Pflanze tritt auffaellig in Erscheinung.

Mit dieser *Barbacenia minuta* zusammen kommt fast immer *Craterostigma plantagineum* vor. Da wo flache Mulden sich im lehmig-sandigen Boden der Steppe bilden, da sucht man eigentlich nie vergebens nach diesem huebschen Pflaenzchen. Ist allerdings der letzte Regen schon vor laengerer Zeit gefallen und hat die Sonne mittlerweile den oberen Bodenschichten alles Wasser entzogen, dann faellt es schwer, in den zusammengeschrumpften Resten, die hellbraun wie der Lehm ihres Standortes ausschauen, die *Craterostigma* zu erkennen. Nach einem kleinen Regenschauer aber scheint sich ein Wunder vollzogen zu haben. Wo eben noch vertrocknete, kuemmerliche Blattreste aus der Erde sich hoben, da liegen jetzt hellgruene, grosse, fleischige Blaetter dicht dem Boden auf. Und auch die zerfetzt ausschauenden Blueten haben sich erholt und zeigen ihr schoenes Blau oder auch Weiss in unversehrter Frische. Und kaum eine Stunde hat genuegt, dieses Wunder zu schaffen. Nicht ganz so rasch vermoegen die kleinen *Barbacenia minuta*—Pflaenzchen diesem huebschen Rosettengewaechs zu folgen; sie brauchen etwas laengere Zeit, aus dem Zustand der Trockenstarre ins aktive Leben zurueckzukehren.

Es macht wahrlich Vergnuegen einige eingetrocknete *Craterostigma*-Pflaenzschen in ein Glas mit Wasser unterzutauchen und der raschen Verwandlung zuzuschauen. Man

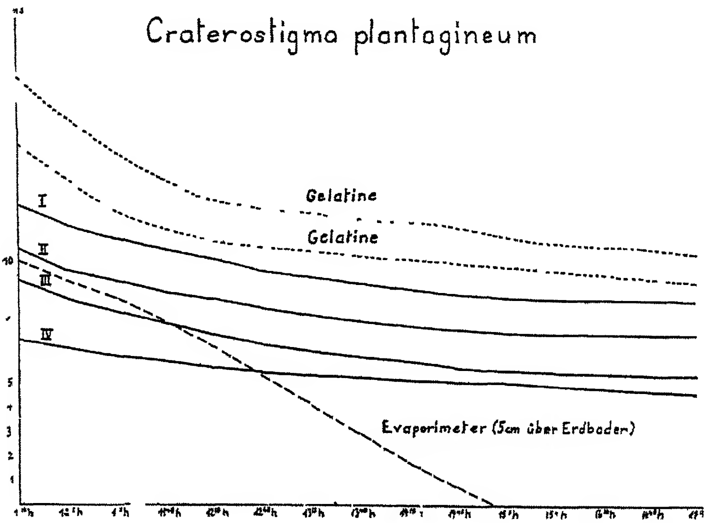

Abb. 5.

Verhaltes von 4 *Craterostigma*-Pflanzen beim Austrocknen. Zum vergleich ist das Verhalten zweier Gelatine-Würfel dargestellt.

kann diesen Vorgang mehrere Male wiederholen, ohne dass die Pflanze dies uebel vermerkt; sie ist immer bereit, von neuem ins Leben zuzueckzukehren.

Abb. 5 zeigt, in welcher Weise die 4 Pflanzen sich beim Austrocknen verhalten. Zum Vergleich legte ich zwei Gelatinewuerfel, die noch etwas Zucker zur Erhoehung des osmotischen Wertes enthielten, in zwei Schaelchen und stellte sie neben den von einer Gummiblase umhuellten *Craterostigma*-Pflaenzchen aus. Das Ergebnis zeigt, dass sie sich ganz aehnlich wie die *Craterostigma* verhalten, dass also die Pflanze sich beim Austrocken durch Wasserverlust ganz wie ein toter, quellbarer Koerper verhaelt.

Wie ueberaus stark die lufttrockenen Pflanzen auf Veraenderungen der Luftfeuchte reagieren, zeigt der folgende Versuch. Eine trockene Pflanze, die 6,81 g wog, wurde fuer die Dauer von zwei Stunden unter eine mit feuchtem Fliesspapier ausgeschlagene Glasglocke gelegt. Nach Ablauf dieser Zeit wurde sie wieder gewogen und wies jetzt ein Gewicht von 7,43 g auf, hatte also um 0,69, d.s. fast 10%, zugenommen. Legte man sie nun wieder in die Sonne, dann verlor sie das aufgenommene Wasser sehr bald, nach 2 Stunden betrug das Gewicht wieder 6,85 g.

Nun versuchte ich festzustellen, wieviel Wasser die Pflanze im lufttrockenen Zustand ueberhaupt noch enthielt. Zu diesem Zweck wurde eine trockene *Craterostigma* im Trockenschrank ganz allmaehlich auf 112° erhitzt. Dabei verlor sie noch ueber 5%; das Gewicht verminderte sich von 2,58 g. auf, 2,43 g. Nun tauchte ich die so behandelte Pflanze wieder ins Wasser, und siehe da, sie ergruente wieder; sie hatte also diese hohe Temperatur ueberstanden, ohne Schaden zu nehmen. Der Versuch wurde nun mehrfach wiederholt, und das gleiche Ergebnis stellte sich ein. Nur in einem Punkte zeigte sich, dass die hohe Temperatur doch gewisse Veraenderungen hervorgerufen hatte: sie brauchten etwas laengere Zeit, um aus dem latenten in den aktiven Zustand zurueckzukehren.

Die hoechste Temperatur, biz zu der man *Craterostigma*-Pflaenzchen erhitzen darf, ohne sie abzutoeten, ist 120° C. Aber diese Temperatur darf nur kurze Zeit einwirken, andernfalls erholen sie sich nicht mehr.

Auch darf man nur voellig lufttrockene Pflanzen im Trockenschrank erhitzen. Geht der Prozentsatz an Wasser, den sie noch enthalten, wesentlich ueber 5% hinaus, dann tritt gleichfalls der Tod ein. Er laesst sich wohl dadurch erklaeren, dass beim raschen Wasserverlust mechanische Zerreissungen im Protoplasma der Zellen eintreten. Chemische Einfluesse scheinen also nicht stattzufinden, sonst wuerde ja das Protoplasma der lufttrockenen Pflanzen gleichfalls abgetoetet werden. Es zeigt sich somit, dass das Protoplasma ausserordentlich widerstandsfaehig gegen alle Einfluesse ist, und dass eigentlich nur mechanische Veraenderungen innerhalb der Gewebe den Tod der Gesamtpflanze herbeifuehren.

In viel geringerem Masse ist die Widerstandsfaehigkeit des Protoplasmas bei den *Barbacenia*-Arten ausgepraegt; aber auch sie lassen sich auf recht hohe Temperaturen erwaermen, ohne dass der Tod eintritt.

Eine solche Pflanze wie *Craterostigma* muesste eigentlich eine ideale Versuchspflanze fuer physiologische Vorgaenge sein. Die Staerkebildung bei der Assimilation duerfte so ohne weiteres abwaegbar sein, wenn man von der lufttrocknen Pflanze ausgeht und die wieder zum aktiven Leben erwachte *Craterostigma* fuer eine bestimmte Zeit dem Licht aussetzt. Die von mir bis jetzt ausgefuehrten Versuche zeigten aber statt einer Gewichtszunahme eine kleine Abnahme. Worauf dies zurueckzufuehren ist, ob vielleicht beim voélligen Eintauchen in Wasser der Pflanze loesliche Salze entzogen werden oder ob beim Uebergang vom latenten zum aktiven Zustand Reservestoffe verbraucht werden, vermag ich bis jetzt nicht zu entscheiden. Eingehende Versuche werden dies sicherlich klarstellen koennen. Denn die Moeglichkeiten, die eine solche ideale Versuchspflanze eroeffnet—ich weise nur auf den Einfluss von Kalium auf die Assimilationstaetigkeit hin—sind zu verlockend. Zudem ist eine Aufsucht der Pflanze in kuenstlicher Naehrloesung verhaeltnismaessig leicht, wenn man nur die Blaetter vor allzu grosser Naesse schuetzt.

Die eigenartigen anatomischen Verhaeltnisse werden zusammen mit den Befunden bei *Myrothamnus* und den *Barbacenia*-Arten veroeffentlicht werden.

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THE INFLUENCE OF LIMESTONE FLOUR AND BONE MEAL FEEDING ON EGG SHELL FORMATION

BY

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With 2 Charts.

Read 6 July, 1937.

Calcium is of great importance in the formation of egg shell. Experiments have proved that cereals are relatively poor in calcium and phosphorus and do not meet the mineral requirements of the animal body. If minerals are deficient in the food, abnormalities in animal growth and reproduction will occur. On the other hand it is doubtful whether all laying hens under forced production can respond to obtimum calcium assimilation for egg shell formation.

A number of factors probably influence the thickness of egg shell. Taylor and Martin, 1928, found a significant difference between two males in the way they bred as expressed by the average per cent. of shell in eggs laid by their daughters. The production of thin-shelled eggs may also be due to an inherited inability to produce heavy shelled eggs under normal conditions.

Knowles, Hart and Halpin, 1935, showed that when a pullet comes into production the rise in the level of blood calcium is due primarily to the increased activity of the parathyroid gland. When an egg shell is being formed the calcium level of the blood decreases, because of the rapid removal of calcium. When the shell is fully formed, the level rises again, because either no more calcium is being removed or a new stimulus is acting on the parathyroid. Deobald, Lease, Hart and Halpin, 1936, injected subcutaneously 1 c.c. of parathormone twice daily into laying hens starved of calcium, and found no apparent effect on calcium metabolism Egg production was not stimulated, the ash content of the bones and the blood calcium remained constant. Single large injections produced a marked rise of the blood calcium three to seven hours after injection in normal actively laying hens.

Wheeler, 1919, indicated that egg shells became thin after a long continuance of a diet low in calcium. Halnan, 1925, found no evidence of the storage of calcium in the fowl prior to egg laying. The increased demand for calcium was met entirely by the increased absorption from the available food supply. Halnan, 1936, reached the conclusion that the mineral limiting factors for egg production were calcium, sodium and chlorine. Experimental evidence showed that improved egg production followed the use of calcium salts, and sodium chloride as mineral supplements. The utilisation of bone calcium for egg production was strictly limited.

Miller and Bearse, 1934, found that hens utilise the calcium of bone meal for egg shell formation. but the egg shells showed a progressive decline in quality throughout the laying year. In these feeding trials bone meal was fed to give four levels of phosphorus, while the calcium content was kept at a constant level by reducing the amount of oyster shell.

Gutowka, 1936, obtained good results when the ration contained 2 per cent. steamed bone meal, 3 per cent. calcium carbonate and 1 per cent. sodium chloride. The bone meal added contained 17 per cent. protein. The Ca : P ration was 1·7 : 1. The addition of the steamed bone meal increased the average weight of the eggs by increasing the weight of shell.

Titus, Byerly, Ellis and Nestler, 1937, fed diets which contained enough bone meal or monosodium-di-hydrogen phosphate to bring the phosphorus content to 1·2 per cent. Ground limestone was added to give Ca : P ratios of 1·0, 2·5 and 4·5 respectively. The pullets and hens did not react in the same way to the higher levels of calcium intake. On the lowest levels the calcium intake (0·9 and 1·2 per cent.) the hens laid more eggs than the pullets, but on the highest levels of calcium intake (4·05 and 5·4 per cent.) the pullets laid more eggs than the hens. They suggested that the level of calcium intake of laying birds should be controlled, and that such control be based on the phosphorus content of the diet, feed consumption and potential egg laying capacity of the birds.

Buckner and Martin, 1920, Buckner, Martin and Peter, 1923 and 1924, obtained the following results at the Kentucky Experiment Station. Hens continue laying eggs until there is a general depletion of calcium magnesium and phosphorus in their bones, and thinning of the egg shells followed by a cessation of egg laying. The percentage of calcium, magnesium and phosphorus in the contents of the egg remained constant during calcium starvation. They also found that calcium in rock phosphate (tri-calcium phosphate) can be utilised by the hen for the growth of bone but not in the formation of egg shell. In the absence of sufficient calcium carbonate fewer eggs are produced than where the available calcium is adequate. In the absence of sufficient calcium carbonate the egg shells become progressively thinner; the percentage composition of the shells, however,

remains constant. Deobald, Lease, Hart and Halpin, 1936, found that about 10 per cent. of the calcium stored in the bones may be called on when there is need of calcium for egg shell formation.

Buckner, Martin and Insko, 1930, indicated that the deposition of calcium carbonate as egg shell, the calcium in the blood coming to the uterus is probably in the form of ionized calcium bicarbonate, calcium phosphate, calcium chloride, and probably some calcium protein complex. Russell and McDonald, 1929, found that laying hens utilise the calcium from calcium citrate for egg shell formation. During egg production more phosphorus was excreted than during non-production.

Although such factors as lack of vitamin D, pathological condition of the oviduct, and extreme heat and cold may cause considerable variation in shell texture, it is certain that an adequate supply of calcium carbonate should be available to the hen for egg production.

Experimental.

In 1932 experiments were started at Grootfontein School of Agriculture to determine whether a supply of calcium carbonate in the form of ground limestone flour could be fed in the mash of laying hens with advantage for egg production, the general health of the bird and the composition of the egg shell.

For this investigation three groups of 17 White Leghorn pullets, bred from the same strain, were placed in separate runs of the same size, and housed under exactly similar conditions. During the day the birds were allowed outdoor and received direct sunlight. Weekly weights of all birds were taken.

The rations were made up as follows:—

(a) Basal mash: 75 lb. wheat brain, 50 lb. pollard, 50 lb. yellow mealie meal and 35 meat meal.

(b) Pen 20 received basal mash.

(c) Pen 21 received basal mash plus 4¼ lb. bone meal.

(d) Pen 22 received basal mash plus 4¼ lb. bone meal and 6¼ lb. limestone flour of low magnesium content.

In addition the birds received equal quantities of yellow mealies as scratch grain and green feed *ad libitum*. During the summer green feed consisted of chopped green lucerne, and during the winter of chopped green barley and oats. All poultry farmers in the Union supply green feed in some form. It was therefore considered necessary to include green feed and test the mineral rations under practical conditions. All birds received tapwater to drink. The granite grit which was available at all times was readily consumed by the birds in pens 20 and 21.

The weekly weights of individual birds were also recorded. The weights of the different groups are given in the following table:—

TABLE 1.

Pen.	Mean Weight, Lb.	Difference.	D/P.E.
	At the Beginning:		
20	3·52 ± ·0408	·10 ± ·0626	1·601
21	3·42 ± ·0475	·13 ± ·0671	1·94
22	3·55 ± ·0474	·03 ± ·0625	0·48
	At 52 Weeks:		
20	3·673 ± ·0811	·042 ± ·0941	0·45
21	3·715 ± ·0477	·198 ± ·0864	2·29
22	3·913 ± ·0721	·24 ± ·1085	2·212

There was an insignificant difference in body weight at the beginning of the experiment. At 52 weeks of age the weight difference was still insignificant. The weight difference between pen 22 and pen 21 increased from 1·94 to 2·29, while the difference between pen 22 and pen 20 increased from 0·48 to 2·212. The weight difference between pen 20 and pen 21 decreased from 1·601 to 0·45. At 52 weeks, the weight difference was more marked between pens 20 and 22 than between pens 20 and 21.

TABLE 2—Number of Eggs Produced.

Month.	Pen 20.	Pen 21.	Pen 22.
1932—September	357	366	350
October	362	397	400
November	340	360	368
December	343	364	343
1933—January	311	357	323
February	249	284	262
March	233	266	228
April	118	166	138
May	15	51	94
June	29	26	54
July	113	105	90
August	243	283	275
Total	2,713	3,025	2,925

TABLE 3—Food Consumption.

Ingredient.	Pen 20.	Pen 21.	Pen 22.
	Lb.	Lb.	Lb.
Total mash, all birds	998·3	1,064·5	1,026
Total grain, all birds	529	547	547
Total grit, all birds	94·1	112·94	52·98
Total	1,621·4	1,724·44	1,625·98
Amount of food per bird	95·38	101·44	95·64
Mash, per bird	58·72	62·61	60·35
Grain, per bird	31·12	32·18	32·18
Grit, per bird	5·534	6·644	3·116
Amount of grain and mash to produce 1 dozen eggs	6·75	6·39	6·44

The feed consumption, the weekly weights of individual birds and the egg production were recorded for 52 weeks (tables 1, 2 and 3). No further records were kept for the following 26 weeks, except observations on mortality and quality of eggs produced. The first thin shelled eggs were obtained from pen 20 on the 21st September, 1933, i.e., 13 months since the commencement of the experiment. At about the same time the first mortality occurred. Two of the birds in pen 20 moulted together with the other birds during the winter period, but these never developed all the contour feathers on the body. Both died in November, 1933. The primary and secondary wing feathers were well grown.

During the 52 weeks period all the eggs were weighed. The total weight of eggs produced in the different pens is presented in the following table:—

Pen No.	Total Weight of Eggs (grams).	Increase (grams).	Average Wgt. per Egg (grams).
20	163891·35	—	60·41
21	175373·1	11481·75	57·97
22	175288·05	11397·7	59·93

Table 4—Remarks on Abnormal Eggs Laid During 18 Months.

Pen 20.		Pen 21.		Pen 22.	
Date.	Eggs.	Date	Eggs.	Date.	Eggs.
17/ 7/33	½ ounce	15/ 7/33	Deformed	—	—
26/ 7/33	½ ounce	25/10/33	Thin Shell	Full period	Normal
21/ 9/33	Thin Shell	—	—	—	—
21/10/33	Thin Shell	—	—	—	—
12/11/33	Thin Shell	—	—	—	—
29/11/33	Thin Shell	—	—	—	—
Total	6	—	2	—	Nil

Mortality.

Pen 20: Four hens died during the spring period 1933. One hen stopped production in June and never laid again. This bird died in October, 1933.

Pen 21: Hen No. 7872 died, the cause being haemorrhage of the liver.

Pen 22: Hen No. 7825 died November, 1933, cause being crop-bound.

During the experimental period there was no indication of infectious diseases on the poultry plant.

The hens in pens 21 and 22 produced a larger total weight of eggs than those in pen 20. The average weight per egg was, however, greater for pen 20 than for either pen 21 or 22.

Every Wednesday six eggs were taken at random from each pen for chemical analysis. During May and June, 1933, production was at a minimum, and eggs had to be taken from the collection of the previous day. In most cases, however, new laid eggs were used.

The chemical analysis was done as follows:—

(a) Eggs were weighed at atmospheric temperature;
(b) Eggs were boiled in water for 12 minutes;
(c) The yolk, albumen and shell membranes were separated from the shell.
(d) The shell was dried at 96 degrees C. in a water oven and weighed.

The liquid contents of eggs were ashed. One portion of the ash was treated with HCl evaporated and gently ignited. Extracted with 10 per cent. H_2SO_4 and phosphoric oxide determined gravimetrically by the ammonium molybdate method. The other portion of the ash was also treated with HCl evaporated and gently ignited. Extracted with 5 μ HCl and calcium oxide determined gravimetrically by the ammonium oxalate method.

The shell was dissolved in HCl made to known volume.

Aliquot volume evaporated and gently ignited extracted with 10 per cent. H_2SO_4 and phosphoric oxide determined gravimetrically by the ammonium molybdate method. Aliquot volume evaporated and gently ignited extracted with 5 μ HCl and calcium oxide determined gravimetrically by the ammonium oxalate method.

The average percentage of CaO and P_2O_5 in the whole egg, the shell and the contents is given in the following table:—

Period September, 1932, to August, 1933.

	Whole Egg.		Shell.		Contents.	
Pen.	CaO	P_2O_5	CaO	P_2O_5	CaO	P_2O_5
20 ...	4·8399	·4873 ...	52·1368	2·0057 ...	·1058	·3353
21 ...	4·9442	·5189 ...	52·8135	2·0420 ...	·1028	·3649
22 ...	5·0072	·5277 ...	53·1403	2·0641 ...	·1052	·3713

Buckner, Martin and Peter, 1923, used the following method for the analysis of eggs.

The shell membranes were not removed but were analysed with the shells. The shells were dried at 100 degrees C. for 24 hours, weighed after cooling and burnt until white. The determination of carbon dioxide, free ash, calcium, magnesium and phosphorus were made with this dry material after grinding and mixing.

Considerable difficulty was experienced in ashing the egg contents, and after many experiments it was found that the best results, accuracy and speed being considered, were obtained by placing the liquid contents of the eggs composing the sample in a porcelain evaporating dish and thoroughly mixing with 5 c.c. per egg of a hot solution of sodium carbonate (80 grams of calcium free Na_2Co_3 dissolved in hot distilled water to 200 c.c.) The mass was then dried at 120 degrees C. and ashed in a platinum dish, a small quantity being placed in the dish at a time. The residue obtained in this manner was easily brought into solution with hot water and hydrochloric acid. The solution was made to 100 c.c., and an aliquot taken for the determination of calcium and magnesium according to the method of McCrudden, while phosphorus was determined in another portion by the volumetric method.

The average percentage of CaO and P_2O_5 in the whole egg, the shell and the contents obtained by Buckner, Martin and Peter, 1924, is presented in the following table. The chemical analysis was done according to the method described above.

Period: November 1 to May 30.

	Whole Egg.		Dry Shell.		Contents.	
Lot and Ration.	CaO	P_2O_5	CaO	P_2O_5	CaO	P_2O_5
1. Corn, buttermilk	3·78	·44	50·6	·36	·071	·45
2. Corn, buttermilk, limestone	4·79	·42	50·6	·34	·068	·43
3. Corn, mash	4·58	·47	51·9	·37	·071	·48
4. Corn, mash, limestone	5·11	·45	51·8	·34	·067	·46

In the present study the percentage P_2O_5 is higher in the whole egg and the shell than the percentage obtained by Buckner, Martin and Peter. The variation in the percentage P_2O_5 in the shell is the most prominent. In the present study the percentage P_2O_5 in the shell varied 2·01 for pen 20 to 2·06 for pen 22, while the percentage P_2O_5 obtained by Buckner and his associates varied from ·34 to ·37 for different groups. In the analysis obtained by the latter workers the percentage P_2O_5 in the egg contents is again higher than the percentage obtained in the present study. The percentage CaO in the whole egg and the shell follow the same trend in both studies. In the present study the percentage $CaCo_3$ computed from CaO in the shell was 92·99, 94·24 and 94·82 respectively.

Wicke, 1863, gave the analysis of the egg shell as follows:—

Constituent.	Per cent.
$CaCo_3$	93·7
$MgCo_3$	1·39
P_2O_5	0·76
Organic material	4·15

Results published by various research workers show some variation in the constituents of the shell. The variation between the results of this study and that of Buckner and his associates may be due to the following:—

(a) Different rations were fed to the laying hens.

(b) In the present study the shell was analysed chemically without the shell membrane. Buckner and his associates included the shell membranes in the analysis of the shell. It is interesting to note that Kelly, 1901, and Clevisch, 1913, found that calcium carbonate is absent in the inner shell membranes.

In the present study the percentage CaO in the shell varied from 52·14 for pen 20 to 53·14 for pen 22. In the study of Buckner and his associates the percentage CaO in dry egg shell varied from 50·6 for the corn and buttermilk group to 51·8 for the corn mash and limestone group.

Hendricks, Lee and Godfrey, 1931, used the following method to determine shell weight. All eggs were weighed and broken and the albumen was washed free from the shell. After being permitted to dry in air, the shells were weighed individually on a balance sensitive scale to ·05 grams. These workers indicated that it has been common practice to compute as a measure of shell thickness the number of grams shell per unit weight of egg. One of the primary requisites of a unit of measurement is that the number of units employed to designate a quantity be directly proportional to the quantity measured. Obviously the thickness of the shell depends upon the weight of shell per unit area of egg. If the egg was a sphere its area would be proportional to two-thirds of its weight. Murray, 1925, showed that the area of the surface of an egg in square centimetres is very nearly equal to 5·07 times the two-thirds power of the weight of the egg in grams. Hendricks, Lee and Godfrey expressed the area of an egg as a function of the weight of the contents rather than as a function of the weight of the entire egg. By dividing the weight of the shell by the two-thirds power of the weight of the contents of the egg, a shell thickness index is obtained which is proportional to the weight of the shell per unit area of egg.

$$\frac{\text{Weight of Shell.}}{(\text{Weight of Contents } \tfrac{2}{3}.)}$$

The example quoted by Hendricks, Lee and Godfrey, 1931, is given. Some idea of the meaning of the index can be obtained by calculating its value for an egg having a good shell. For a 57 gram egg having a shell weighing 5·7 grams, the index I was calculated as follows:—

$$I = \frac{5 \cdot 7}{(51 \cdot 3)^{\frac{2}{3}}} = \frac{5 \cdot 7 \sqrt[3]{51 \cdot 3}}{51 \cdot 3} = 0 \cdot 413$$

The shell thickness index was also determined in the present study. The results are presented in graphical form (Figure 1). During the first six months no consistent differences are shown between the three pens. From the seventh month the egg shells from pen 20 (basal food alone) became thinner. During the eleventh month the shells from this pen became suddenly thicker. Hendricks, Lee and Godfrey, 1931, observed that the shells became consistently thinner from the ninth to the fourteenth period for the basal group. After the fourteenth period the shells from this group became suddenly thicker. These workers could offer no satisfactory explanation for this change. In the present study this sudden increase of shell thickness in the basal group occurred during an increase in production after the moult (Figure 2). The sudden increase in shell thickness in both studies occurred during the winter period. Bennion and Warren, 1933, found that all components of the egg decreased under a high temperature; the shell and albumen decreased considerably more than the yolk in proportion to their weight, which indicates that the oviduct is more sensitive than the ovaries to high temperatures. The mean daily egg size of birds placed under controlled temperature was reduced from 15 to 20 per cent. by the application of high temperatures. The egg size declined much more rapidly under high temperature than it increased when the temperature was lowered. In the White Leghorns and Rhode Island Reds studied, both breeds reached their maximum egg size in the early part of February; from then until the latter part of May, when summer temperatures began to have their effect, there was very little fluctuation in egg size.

Discussion.

Experiments have indicated that a number of factors influence the thickness of egg shell. Although such factors as lack of vitamin D, pathological conditions of the oviduct, and extreme heat and cold cause considerable variation in shell texture, it is certain that an adequate supply of calcium carbonate should be available to the hen for egg shell formation. Buckner, Martin and Peter, 1923, indicated that an egg contains about 2·5 grams of CaO, and they estimated that five eggs require about 12·5 grams of CaO for their formation.

The birds which received mineral supplements of bone meal and limestone flour in the ration were slightly heavier in weight at 52 weeks than those which were fed on the basal food plus bone meal only. Buckner and Harms, 1935, observed that the addition of calcium carbonate to the basal ration caused an increase in the digestion of protein in the mash. In addition, calcium aids in the neutralisation of organic and inorganic acids in the body and improves the calcium phosphorus ratio.

Both the bone meal and the bone meal limestone flour groups appeared in a better physical condition at the end of the experiment than the basal group. The basal and bone meal groups

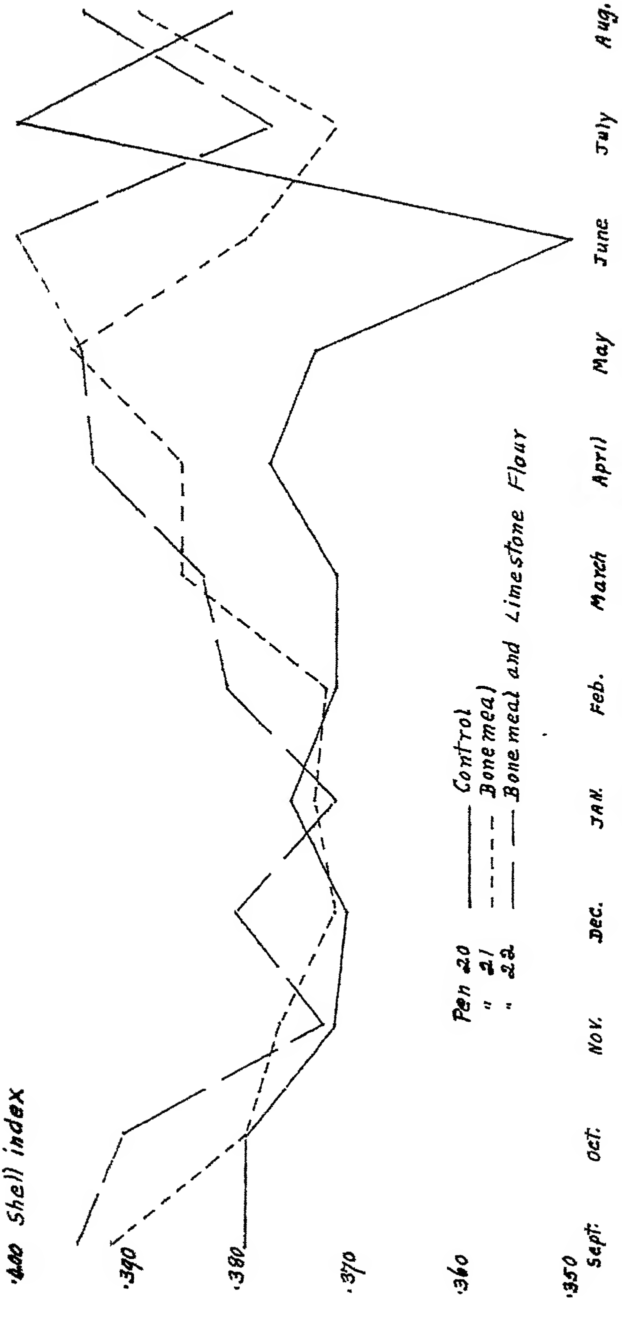

Figure. I. AVERAGE SHELL-THICKNESS INDICES OF EGGS

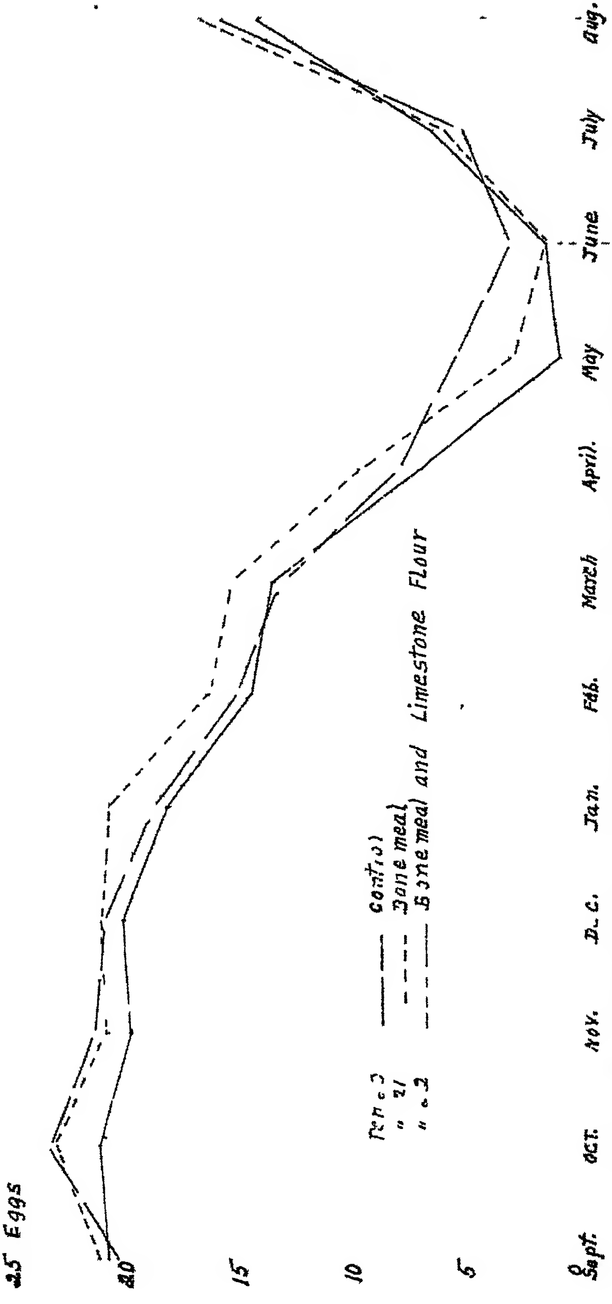

Figure 2. AVERAGE PRODUCTION PER BIRD PER MONTH

always appeared very nervous. This was especially noticeable at the time of weighing. The bone meal group (pen 21) produced the most eggs. This group consumed twice as much grit as the bone meal limestone flour group (pen 22). The small amount of available calcium in the granite grit probably encouraged birds to consume grit, and in this way counteract the deficiency of calcium in the food. Both the basal group (pen 20) and the bone meal group (pen 21) developed an abnormal appetite for grit.

The egg shells obtained from the bone meal limestone flour group (pen 22) were heavier than those obtained from the bone meal group (pen 21). The egg shells of the basal group were definitely inferior. Buckner and his associates, 1923, found that in the absence of sufficient calcium carbonate the shells became progressively thinner; the percentage composition of the shells, however, remained constant. In the present study the percentage $CaCo_3$ computed from CaO in the shell varied from 92·9 for the basal group to 94·8 for the bone meal limestone flour group. From the fifth to the tenth month the bone meal limestone flour group showed a fairly consistent increase in shell thickness. When calcium carbonate is added to the ration of laying hens, poultrymen in the Union can expect eggs of good shell texture during February, March, April, May and June. During November, December and January, shell texture will be poorer. Indications are also that hens fed on an adequate supply of calcium carbonate in the ration will produce eggs of better shell texture during the summer months than birds fed on a low calcium diet.

The most popular supplements of calcium carbonate to poultry rations are oyster shell and limestone flour. Some poultrymen include from 3 to 5 per cent. of oyster shell powder or limestone flour in the mash. In addition oyster shell is fed in separate buckets. Others again include 2 to 3 per cent. of bone meal in the mash and provide oyster shell *ad libitum* in separate buckets. Both these systems of feeding minerals will probably give good results.

Oyster shell is a good source of calcium as it contains approximately 93 to 94 per cent. calcium carbonate. Limestone flour from different sources vary in the percentage calcium carbonate. Research work has indicated that limestone flour low in magnesium oxide can replace oyster shell as a source of calcium carbonate for egg shell formation.

Results of the present study indicate that hens can utilise the calcium of bone meal for egg shell formation, but optimum calcium requirements are not met for the manufacture of a good quality shell.

Halpin and Lamb, 1932, did not consider the calcium supply as a stimulus to egg production, but only as a possible cause of limitation of production. Halnan, 1925, gave a good illustration of the deficiency of wheat to supply the calcium required for the

formation of an egg. A hen fed on wheat alone must eat nearly 12 pounds of wheat to supply sufficient calcium for one egg. This is impossible, as a laying bird only consumes from 3 to 5 ounces of mash and grain per day. This illustration is clear enough, and indicates that the grain and mash ration should be supplemented with adequate mineral constituents. A supply of oyster shell or ground limestone flour to the ration should at least assist a laying bird in the production of eggs of good shell texture. Such eggs should also reduce the waste in breakage on a poultry farm.

Summary.

1. The birds which received mineral supplements of bone meal and limestone flour in the ration were slightly heavier in weight at 52 weeks than those which received the basal food plus bone meal only.

2. Both the bone meal and bone meal limestone flour groups appeared in a better physical condition at the end of the experiment than the basal group.

3. Both the basal and bone meal groups developed an abnormal appetite for grit.

4. The egg shells obtained from the bone meal limestone flour group were heavier than those obtained from the bone meal group.

5. The bone meal group produced the most eggs, but the egg shells were lower in calcium than the egg sobtained from the group which received limestone flour in addition to bone meal.

6. Eggs of poor shell texture were more prevalent during November, December, January and February than the other months of the year.

N.B.—The results published in this paper were obtained by the authors while stationed at the Grootfontein School of Agriculture, Middelburg, Cape Province.

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PUBLIC HEALTH AND MEDICAL SERVICES IN SOUTH WEST AFRICA

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Read 6 July, 1937.

It is with the greatest diffidence that this paper is presented, As indicated by its title it is not a scientific contribution, though, in passing, matters may be touched upon which offer a very fertile field for investigation.

Public health as we know it to-day embraces a vast variety of matters, and if given its due consideration cannot be divorced from social and economic questions. Education is a potent factor falling within its ambit. The educationist would perhaps prefer to reverse this statement. However that may be, the aim and object of all public health measures should be to bring about communal happiness, even if the individual and sometimes even the local authority is apt to consider himself or itself the injured party.

In order to appreciate the trend of these very general remarks in regard to public health as applied to this Territory, it is necessary to briefly survey the situation.

First of all South West Africa is comparatively speaking a very young country, which has passed through exceedingly turbulent times. Even to-day things are not as tranquil as they may outwardly appear to be, but with this particular aspect we are not directly concerned. According to the information I have gathered missionaries first settled here about 100 years ago, and soon afterwards they induced German settlers to come out with the object of inculcating European ideas. This project did not apparently meet with any measure of success. It was not until 1884 that a European power began to take an active interest in this country. Up till then tribal, or rather racial, warfare as between the Hottentots and the Hereros was the order of the day. This state of affairs continued until well into the present century, the situation being further complicated, shall we say, by the European power which was endeavouring, for the purpose of colonisation, to bring about law and order. This unsettled state ultimately culminated in 1907 in the downfall of the Hereros who were then the dominant native race. Thus it was virtually only from that year that colonisation can really be said to have commenced.

The next point to consider is one of dimensions. The Mandated Territory of South West Africa, including Walvis Bay area, which is a mere 374 sq. miles in extent, covers an area of over 318,000 sq. miles. Thus this Territory is roughly two-thirds the size of the Union of South Africa, and a few of its magisterial districts are larger than the Orange Free State.

This vast expanse of territory can be conveniently divided into the following areas, firstly, the so-called police zone, which is approximately 198,000 sq. miles in extent. This area includes a number of native reserves (17), the majority of which have been established since the Union took over the mandate, also the Rehoboth Gebiet, a game reserve, and the Sperr Gebiet—the latter area being diamondiferous. The police zone is the area throughout which a European may roam without a permit, that is with the exception of the native reserves and Sperr Gebiet; secondly, we have the Kaokoveld (area 37,588 sq. miles); thirdly, Ovamboland (area 16,216 sq. miles); fourthly, the Okavango region, which is inhabited along the river for a distance of some 250 miles, and lastly, the Caprivi Zipfel (area 7,479 sq. miles). These latter areas are all native reserves.

In regard to the physical features, these range from uninhabitable desert country to subtropical and tropical areas, where nature provides all the requirements of primitive man. I am particularly referring to the belt along the Okavango river. As will have been gathered from the foregoing statement there is a great disparity in the rainfall. It varies in fact from a fraction of an inch per annum on the coastal belt to an average of 22 inches per annum in the north. The average annual rainfall in the hinterland, however, diminishes as one proceeds southwards. The average annual rainfall in the most southern district, Warmbad, is in the neighbourhood of six inches.

In Ovamboland in a normal rainy season, or if abnormal rains have fallen in Angola, as is the case this year, practically three-fifths of that country becomes inundated; if, on the other hand, the rainfall is below normal, the country very soon becomes parched, and unless provision has been made for lean years a famine ensues. Ovamboland, I should mention, is as flat as the proverbial pancake.

This Territory, as a whole, is normally a drought-stricken one; by this I infer that droughts are not the exception but rather the rule, and in contrast to this every so often a deluge occurs, one which was unprecedented in living memory occurred in 1934, when all normal modes of transport were entirely dislocated, in fact even landing grounds became unsafe. Thus it will be seen that this Territory is subject to many vicissitudes, and that it is by no means all "beer and skittles."

A few words should also be said in regard to the population. I shall not, however, dwell on this subject. From a vital statistics point of view the situation has been, and still is, most

unsatisfactory, both as regards European and even more in the case of native statistics. Most countries have a considerable mobile population, but if the changes wrought in this Territory during the past 25 years had been accurately recorded it will be seen that the population figures do not as yet lend themselves to analysis for public health purposes. There is, however, very little consolation to be drawn from this fact.

In 1913 the European population was stated to have been 14,830. I have not been able to ascertain how many males there were as compared with females, but it can be taken for granted that the former far outnumbered the latter. Of the 14,830 over 6,000 persons were repatriated.

In May, 1921, when the first census was taken, the European population was 19,432—adult males 6,909, adult females 3,866, minors 8,657—the sexes being about equal in number.

In 1926 the European population was 24,115—adult males 8,272, adult females 5,030, minors 10,813—the sexes again being about equal.

At the census taken in 1936 the European population was, according to the preliminary figures, 30,505—male adults 9,411, female adults 7,433, minors 13,661—male children being slightly in excess.

Having regard only to the police zone, the density of the European population is about 0·2 of a person to the square mile, and if urban residents are excluded the density of the rural population is about 0·1 of a person.

As regards the native population we are really very much in the dark. It is estimated, however, that there are about 300,000 natives in South West Africa. Half of this number reside in the northern territories, Ovamboland being the most densely populated area. The Ovambos far outnumber the other tribes of South West Africa. Although, according to the reports received from certain quarters, the infant mortality is appalling —this, by the way, is not peculiar to South West Africa—nevertheless, I have no hesitation in saying that the native population is definitely on the increase, even in the face of statements that barrenness and sterility are prevalent as a result of the incidence of venereal diseases.

In my opinion the native to-day, though still very primitive, is enjoying a measure of happiness which he has never experienced before.

The foregoing remarks have, I hope, given you a rough idea of the country. It is, even taking the natives into consideration, a very sparsely populated Territory, and one that, on account of its very nature, will never be able to support a large population unless large quantities of minerals of daily commercial value are discovered. It is a poor country, being essentially a pastoral one.

Its chief source of revenue in the past has been derived from diamonds, which has proved a very fickle one, and one which I make bold to say has done this country more harm than good as it created a false sense of wealth and put grandiose ideas into the heads of some people.

The European birth-rate compares very favourably with the death-rate, that is, based on the meagre information one has to work on. The situation, however, is such that even to-day difficulty is being experienced in finding livelihoods for the youth of this Territory. What to-morrow holds in store is going to prove a most difficult problem. It is not my intention to create a gruesome picture, but this Territory is no " Lotus land," though, strangely enough, most people who have resided in it for any length of time always have a hankering for it.

Is this country a healthy one? In normal years—yes; and also if there is a prolonged drought, that is in-so-far as preventable infectious diseases are concerned (I am of course disregarding the infectious diseases of childhood, which have much the same periodicity here as elsewhere), but the native population definitely suffers as scurvy and tuberculosis, especially amongst the Hottentots in the south, come to the fore, and a large percentage of the European population is not immune to the effects of a prolonged drought and the consequences which ensue, as malnutrition becomes quite a marked feature.

If an abnormal rainfall is experienced, the country definitely becomes unhealthy—malaria becomes rife and epidemics of enteric fever are apt to occur.

Taking it all in all the climate of South West Africa is a trying one, though the heat in summer is rarely excessive, the winters are usually shortlived and extreme cold is seldom experienced; but the relative humidity throughout the greater part of the year is too low.

The dryness of the atmosphere probably accounts for the prevalence of naso-pharyngeal catarrh and the frequency of the eye condition Pterygium—a thickening of the conjunctiva at the inner canthus.

Speaking of the health conditions in general reminds me of a certain official who had occasion to write in glowing terms of South West Africa, yet every year he took the precaution, so it is alleged, to be inoculated against enteric fever.

If what I now have to say about public health during the German regime sounds very disparaging, it must be borne in mind that the country did not settle down until 1907 and that it was essentially a garrison country. This fact is even reflected in the houses they erected. They were built without a thought being given to comfort or convenience, and are veritable refrigerators during the winter months, fit only for Spartans, and not for persons whose blood has become thin either as a result of their long residence in a country where it is summer for the

greater part of the year, or to South West's national pastime—the sundowner; which of these factors has played the more important rôle I am not prepared to say.

It is recorded that in April, 1908, there were 41 military doctors in this Territory, whereas there was only one whole-time medical officer in the employ of the Civil Administration, four private medical practitioners, two of whom were part-time Government officials, and four railway and mine medical officers. Thereafter the number of civil practitioners increased while the military doctors diminished in number—that was until 1912.

There was no Government legislation in regard to heatlh matters, each township or dorp having its own regulations dealing primarily with the fundamentals of public health. It was the duty of the part-time Government medical officers to keep an eye on public health matters, but according to German reports they were more concerned about their private practice than general health matters. Enteric fever, dysentery and malaria were very prevalent. Flies were a positive pest. Windhoek was, in fact, one of the worse places. This is not to be wondered at, as will be gathered from the following extract taken from a report written early in 1916 by one of the senior medical officers of the Army of Occupation. He states:—

> "The system of sanitary removal in the inland towns was as follows:—
>
> "Collect stercus, offal and rubbish, and dump (preferably in a river bed about a mile or so from the town) and leave the festering mass unburied, uncovered and unpoisoned, or unburnt. The result was the breeding out of enormous fly swarms which duly returned to town with the animal transport from the dump. As it is now proved beyond doubt that the fly is the chief carrier of enteric, dysentery, summer enteritis of children, etc., it is easy to explain the heavy incidence of these diseases under the German regime."

This was apparently the position when the Union troops took command. It would appear that the German idea of public health was not to attack the cause but if possible to give an inoculation against the disease, in other words prophylaxis as against prevention, which is essentially an army method of dealing with the situation.

During the period martial law was in force, that was from 1915 to 1920, officers of the military constabulary who had been trained in sanitary methods supervised the sanitation in the towns in which they were stationed.

In the annual report for 1918 the following statement appears under the heading Sanitation:—"It is worthy of mention that the German population have been particularly impressed with the improvements effected in this direction since our occupation. During the previous regime, it is said, it was the exception

rather than the rule to rear an infant in Windhoek. Now infantile mortality is inconsiderable."

On the other hand the following statement, which appeared in the report previously alluded to, and which reads as follows:— "Unfortunately also German municipal officials were prepared to argue on the merits of their system and are altogether rather difficult to educate to more modern views"—rather struck me, as even to-day similar experiences are being encountered.

In 1920 the military regime came to an end, and 1921 saw the commencement of civil administration, which is much the same to-day except that a measure of self-government was granted in 1925 by the South West Africa Constitution Act, the wisdom of which has recently, as you will no doubt recall, been questioned. However, public health is one of the subject matters over which the Parliament of South West Africa has full legislative powers.

The Union Public Health Act, 1919, was applied to this Territory in 1920 with certain modifications, for instance, the functions of the Government and the Provincial bodies were of necessity rolled into one. This fact does not appear to be fully appreciated; by this I mean that we are not only concerned with medical services, such as hospitals—a provincial matter—but also public health policy. Up to now the outlook, I regret to say, has been almost entirely provincial, and even this aspect has its shortcomings, as there is no medcial inspection of school children.

The provincial attitude may be due firstly to the fact that in applying the Act those sections dealing with the functions of the Public Health Department were deleted, in other words the very kernel of the Act was taken out, nevertheless, the Public Health branch of the Administration is being confronted continually with all sorts of problems which are likely to increase as time moves on. Secondly, the Territory is still regarded as being in the pioneer stage, and as you know pioneers must fend for themselves, but unfortunately this Territory has its fair share of paupers, that is leaving the native entirely out of the picture. and as previously indicated poor whiteism is going to be one of this country's major problems, unless I am very much mistaken.

Thirdly, the Public Health Act was framed ostensibly for the control of large commuities. Windhoek, the largest town in this Territory, has only a population of roughly 11,000 (5,000 Europeans and 6,000 natives).

Lastly, and by no means least, the financial resources of this Territory are very restricted and there is much ground to cover, speaking both literally and metaphorically.

Under the provisions of the Public Health Act the Local Authorities are responsible for the sanitary and other measures necessary to safeguard public health in their respective areas, the

Administration rendering financial assistance in certain well-defined matters.

A few of the Local Authorities have appointed part-time Medical Officers of Health; in other areas the District Surgeon is called upon to give advice on health matters, and he not infrequently refers the matter to head office. No Local Authority has had, until quite recently, a certificated sanitary inspector in its employ—in fact there is at the moment only one such officer in the Territory.

At present, therefore, as I think I have already indicated, modern public health measures are still being dreamt about, but everywhere steps are being taken to safeguard health in so far as the first essentials are concerned, that is the provision of a wholesome and adequate water supply and hygienic methods of waste product disposal. These are matters which in more advanced countries have passed almost entirely out of the hands of the medical officer and are being dealt with almost exclusively by engineers.

Practically throughout this Territory, with the exception of Windhoek, where there is a water-borne sewerage system, though the whole town has not been linked up with it, the methods of disposal have of necessity to be conservative, as one of our greatest difficulties is that of obtaining an adequate water supply. In Luderitz, for instance, condensed sea water is used for domestic purposes, the price of a bath being almost prohibitive. Here in Windhoek a dam was built costing some £120,000. It was filled to overflowing in 1934, yet to-day the municipality has had to fall back on the hot springs and boreholes for its public water supply.

Further, it is not only the question of ample supplies but also quality. The majority of waters used in this Territory contain a high percentage of salts, and a number of them are distinctly brackish. Practically in all cases where samples have been sent to the Union for chemical analysis reports have come back to the effect that the water is unsuited for domestic use; nevertheless, such waters have to be made use of and people seem to thrive on it. It seems to be purely a question of accommodating oneself, though really this question requires systematic investigation. While on the subject of water, a matter which really calls for investigation should be referred to. It is the discoloration found in the teeth of the second dentition of quite a fair percentage of European children, who have been brought up in Windhoek in particular. I understand it is also met with at Keetmanshoop. The water may have nothing to do with it, though an opinion has been voiced that the hot springs here contain fluorin salts, and that these salts are responsible. The question immediately arises as to why the natives are immune.

Besides the matters referred to above an endeavour is also being made to protect the public from the sale of unwholesome foodstuffs, especially in the case of perishable foods, but probably

with the exception of meat inspection, and this is not carried out everywhere, the control exercised leaves much to be desired. Regulations have in many instances been promulgated, but the machinery is lacking. Again it is a question of pounds, shillings and pence. It should, however, be added that control is being exercised over the butter industry, and every endeavour is being made to get farmers to produce first grade cream, the grade depending almost entirely upon the cleanliness observed. It might be mentioned that over 75 per cent. of the cream produced at the milk depots established in the native reserves is first grade.

Passing now on to the question of preventable diseases, the incidence of enteric fever is usually taken as the index of the state of public health of a country. To-day I am pleased to say that but few cases of enteric occur. I must admit, however, that this is not entirely due to improved sanitation; we have to thank Providence to a great extent, that is to say the sunshine we enjoy for practically 365 days of the year and the aridness; for loopholes in the conservative methods employed have been revealed on more than one occasion when the rainfall has been abnormal. These loopholes are due, in my opinion, to a certain amount of carelessness. If things proceed smoothly for a number of years, there is a general attitude of complacence, and slipshod methods are apt to be overlooked. This occurs even in the face of bitter experience.

Typhus fever, a disease which is definitely an indication of the facilities provided and measures taken to raise the standard of living of natives, especially those residing in our immediate precincts (and this fact should not be lost sight of) made its appearance in South West Africa for the first time to the best of our knowledge in 1934. Keetmanshoop was the chief seat of infection. Since then the disease has spread further afield, and we have had typhus in Windhoek, though fortunately it did not reach alarming proportions as was the case at Keetmanshoop. The disease here is entirely louse-borne, and, therefore, amenable to eradication, though I have heard it said that the Hottentots regard lice as part and parcel of themselves.

The abovementioned diseases may be looked upon as diseases, the prevention of which is primarily the concern of the Local Authorities, though I must admit that the enteric fevers offer special difficulties, as the detection of the carrier is not a simple matter, even in countries where there are laboratory facilities at hand; furthermore, the solution of the carrier problem, especially in countries where natives far outnumber the Europeans, bristles with difficulties.

Several other diseases might very well be referred to, but they all call for specialised handling, that is from a preventive aspect.

Coming now to the diseases of more national consequence we have first of all malaria. Normally this disease is confined to

certain districts, mostly in the north, where it has a seasonal prevalence. In Ovamboland, and more so in the Okavango region and Caprivi Zipfel, the disease is endemic. In the districts previously referred to and even in other districts epidemics occur from time to time. I do not see how they can be prevented in a country which is sparsely populated and where, after heavy rains, large collections of water appear. In normal years if proper precautionary measures are taken I see no reason why this disease should not be reduced to a minimum, and in this manner it should be possible to stamp it out, but natives are continually coming down from the northern territories either to work on the mines or farms, and they practically one and all harbour malaria parasites.

As regards venereal diseases, these diseases are prevalent among the natives, but the incidence is not as high as it is frequently alleged to be. The Administration is endeavouring to make it possible for all natives suffering from these diseases to receive treatment. What is not very satisfactory is the fact that we have not the facilities for controlling treatment. I am referring to the necessity of having Wasserman tests performed in the treatment of syphilis. However, the percentage of tertiary and secondary cases presenting themselves for treatment has fallen considerably of recent years. Neuro-syphilis is also very rarely met with amongst natives. Gonorrhoea, unfortunately, is regarded very lightly by the natives, and as a rule only advanced cases come for treatment. A probable factor is that the treatment of this disease is not as dramatic as that of syphilis.

I shall only briefly refer to plague. Human cases of this disease were first discovered in Ovamboland in 1932. Investigation revealed that cases had occurred towards the latter end of the previous year. As yet human plague is confined to Ovamboland. Since the disease first made its appearance until May of this year 670 cases, 93 deaths, have been notified. According to the case mortality here, as compared with that in the Union, it would seem as if the plague bacillus has become attentuated during its passage over the Kalahari.

After the abnormal rains of 1934 the whole Territory became absolutely overrun with rodents; even here in Windhoek the position was such that the striped mouse actually entered dwellings. The spread of human plague was feared, but nothing eventuated, except for an alarm which was raised at Outjo. Today there is hardly a rodent to be seen in the vicinity of Windhoek. You may also have heard that there are no fleas to be found in Windhoek. I am inclined to doubt the veracity of this statement, though from a plague point of view I would like to believe it.

Undulant fever, commonly known as Malta fever, is another disease met with in this country. During the Great War it is stated that more cases of this disease occurred amongst the troops in South West Africa than in all the other war zones. It is a

disease which does not lend itself to clinical diagnosis, especially when it can be confused with malaria, enteric fever and even influenza. It was first thought that undulant fever was confined to the south of this Territory, but of late several cases have accurred in the northern districts. It is another of those diseases which calls for serious investigation.

Tuberculosis, though rarely found in Europeans, is not uncommon amongst the natives, who are very subject to respiratory diseases, and pneumonia is not infrequently superseded by tuberculosis, which, when once contracted, runs a very rapid course. Though this disease was most prevalent amongst the Hottentots in the south, its incidence to-day is greatest amongst those natives living at the coast. This disease is now unfortunately found throughout the length and breadth of this Territory. Much as civilisation and syphilisation have been said to be synonymous, so too is tuberculosis one of the diseases which follow in its wake.

The more important diseases have been touched upon, but before outlining the medical services, a subject which will not be laboured, it should be mentioned that a very watchful eye is being kept on the health of natives employed on mines, where, of course, there are mine medical officers; and the conditions under which native and coloured persons are required to work in the crayfish factories are also being looked into.

Medical Service.

There are only two whole-time medical practitioners in the employ of the Administration, the Medical Officer and the District Surgeon, Ovamboland. In addition there are, within the police zone, 14 part-time district surgeons, and in all there are some thirty odd registered medical practitioners in the Territory and nine of them reside in Windhoek.

There are five state-aided hospitals and nine private or semi-private hospitals or nursing homes. Two of the state-aided hospitals and two of the mission hospitals have accommodation for native patients. The Government also maintains three native hospitals, namely, at Windhoek, Keetmanshoop and Omaruru. These latter hospitals have all been built or rebuilt since the Territory became a mandate. Native patients suffering from any disease whatsoever are admitted to these hospitals. Until quite recently they were staffed by unqualified native assistants, Europeans who were formerly members of the S.A.M.C. being in charge. Two qualified native nurses are now employed at Windhoek, and an endeavour is being made to gradually increase their number. There are also five venereal disease compounds.

As regards the native reserves, a medical orderly is being stationed in each reserve for a period of three to four months. This, in brief, is the position within the police zone.

In the Kaokoveld itself, which is inhabited by Hereros, there is no medical assistance. These natives travel to Ondangua,

Ovamboland, for such aid, and the District Surgeon of Ovamboland visits that area once in a while.

In Ovamboland the medical work is for the most part in the hands of the missions. The Finnish Mission, which does the brunt of the work, has two quailfied doctors stationed there; both are women. This mission maintains two hospitals, and another hospital is at the moment being erected. The Anglican Mission has a small hospital which is in charge of a qualified sister. The Roman Catholic Mission has clinics in charge of qualified sisters.

The District Surgeon, whose headquarters are at Ondangua, besides having to examine all native labour recruits, has to travel periodically throughout his area. There is also a rodent officer whose chief duty is to wage a continual campaign against plague, keep the native alive to the situation and inform head office as to rodent activity and the flea index. From the data furnished one endeavours to forecast the probable incidence of plague—our great fear being the occurrence of pneumonic plague.

Before leaving this area it should be mentioned for the benefit of those who may be interested that purpura haemorrhagica is quite a common ailment, and that Ovamboland therefore, offers ample material for the investigation of a blood disease the cause of which we know little or nothing about. This disease, by the way, is also met with in the Territory proper, and several cases are usually admitted to the native hospital during the course of a year.

In the Okavango region the medical work is entirely in the hands of the missions—the Finnish Mission in the western area and the Roman Catholic Mission in the eastern portion. The latter mission recently stationed a qualified medical practitioner at a place called Nyangana. This doctor now supervises the medical work of the mission. Leprosy is alleged to be prevalent in this region.

All the missions referred to receive drugs, etc., free of charge from the Administration, and also receive grants varying in amount towards their medical work.

In the Caprivi Zipfel, which is probably as foreign to the inhabitants of this Territory as to the majority of those attending this meeting, there is only one mission station which, according to reports, renders little or no medical assistance. The natives obtain their medical aid from the Paris Mission at Sesheke in Northern Rhodesia. To reach this strip of country the normal procedure is to go via Livingstone, thus to all intents and purposes it is cut off from this Territory.

I have of necessity had to be extremely sketchy in my remarks on medical services and much has been left unsaid in regard to public health. It is hoped, however, that a fair idea of the situation has been given, and that though as the President has remarked "There is nothing new under the sun," yet this country, like most other countries, has problems which are peculiar to itself, but unfortunately it has no archives to fall back upon.

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THE HYOID BONE OF NEGRO AND PRE-NEGRO SOUTH AFRICAN RACES

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With 6 Text Figures.

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Introduction.

As is evident from the available literature on anthropology, the human hyoid bone is seldom preserved with other fossilised material. Yet at times even a bone as small and fragile as this may have a tremendous anthropological value. So little is known, however, regarding the comparative features of the human hyoid, that it is impossible at present to interpret the structural features of any individual specimen.

Judging by the great anatomical importance of this small skeletal element to which are attached no fewer than eighteen muscles, five ligaments and several fascial condensations, it must be evident that it may be of outstanding significance from the point of view of anthropology. Moreover, the variations of its morphological appearance, which occur in different primate groups, indicate that it is a bone which is easily moulded in accordance with the particular function it subserves. In man, furthermore, the hyo-mandibular mechanism, in addition to being used during mastication, deglutition and related processes, has also acquired additional importance as an accessory speech apparatus. In different primate groups, the hyoid bone appears to be readily modified in accordance with function. It seems reasonable to expect an analogous modification in various human races in accordance with the different types and degrees of development of the speech faculties. Additional factors may naturally also influence the shape of the bone, such as different types of diet, gross modifications of the mandibular and facial bones, etc.

The evolution of the chin region of the human mandible has, moreover, not been satisfactorily explained as yet. Much importance has been attached by some authors to the effects of muscular traction by the genio-hyoid, genio-glossus and digastric muscles on the form of this part of the mandible. In so far as the genio-hyoid, mylo-hyoid and digastric muscles are also attached directly, and the genio-glossus attached indirectly (but according to Parsons, also directly) through the hyo-glossus to

the hyoid bone, it is important to determine the traction effects of these muscles on this bone as well, for, depending on the type of traction, it must be evident that the effects should be similar and proportional to those on the mandible.

It follows then that the anthropological investigation of the hyoid bone cannot but be an important matter.

Material.—It has been the good fortune of the Department of Anatomy, University of the Witwatersrand, to have secured in recent years several valuable specimens of hyoid bones. Through the courtesy of the Director of the MacGregor Museum, Kimberley (M.M.K.), it has been possible to examine seven hyoid bones of alleged known Bush origin. These specimens were all fairly well preserved and corresponded to the following skeletons:—M.M.K. 144, a young adult female; M.M.K. 151, a middle-aged male; M.M.K. 161, an elderly male; M.M.K. 165, a young adult female. These were collected from Gordonia. M.M.K. 174, a middle-aged male comes from Bushmanland, and M.M.K. 143, also a middle-aged male, from Kuruman. M.M.K. 166, an elderly female, was found at Karasberg, South-West Africa.

One well preserved fossilised hyoid bone belonging to the pre-Bush material from the Zitzikama caves was available for examination. No further information could be obtained regarding the level at which or the skeletal material in association with which it was discovered. The specimen consists of the body and the greater cornua. Both lesser cornua are missing.

The hyoid bone discovered in the Mapungubwe deposit consists of the body and the left greater cornu. It is not as heavily fossilised as the Zitzikama specimen. It was discovered with skeleton M. 5 (Sceptre skeleton).

For comparison, South African Negro and European hyoid bones were used. In the case of the latter, as no specimens were available, it was necessary to rely on text-book accounts and the papers by Parsons. These descriptions indicate that it possesses characteristic features, but insufficient information is recorded for a detailed anthropological description to be possible. The South African Negro hyoids were, for the most part, examined in dissected adult cadavers.

For convenience of description, and also on the basis of its essential anatomical character, the hyoid bone will be subdivided into the corpus or body, the two greater and the two lesser cornua. The contours of the various hyoids are supplied in Figs. 1 to 6. The metrical data are assembled in Table 1.

Description.

1. *Anatomical Features.*

(a) *General Build of the Hyoid.*

Amongst the seven specimens of hyoid bones of the Bush race, two distinct groups may be recognised. M.M.K.

143, 166 and 161 are large and in certain respects resemble one another, and differ from M.M.K. 174, 144, 151 and 165, all of which are small. In addition to the differences in the morphology of these groups, considerable individual variations are observed, which cannot be correlated with either sex or age. The general build of the Bush hyoid is slender.

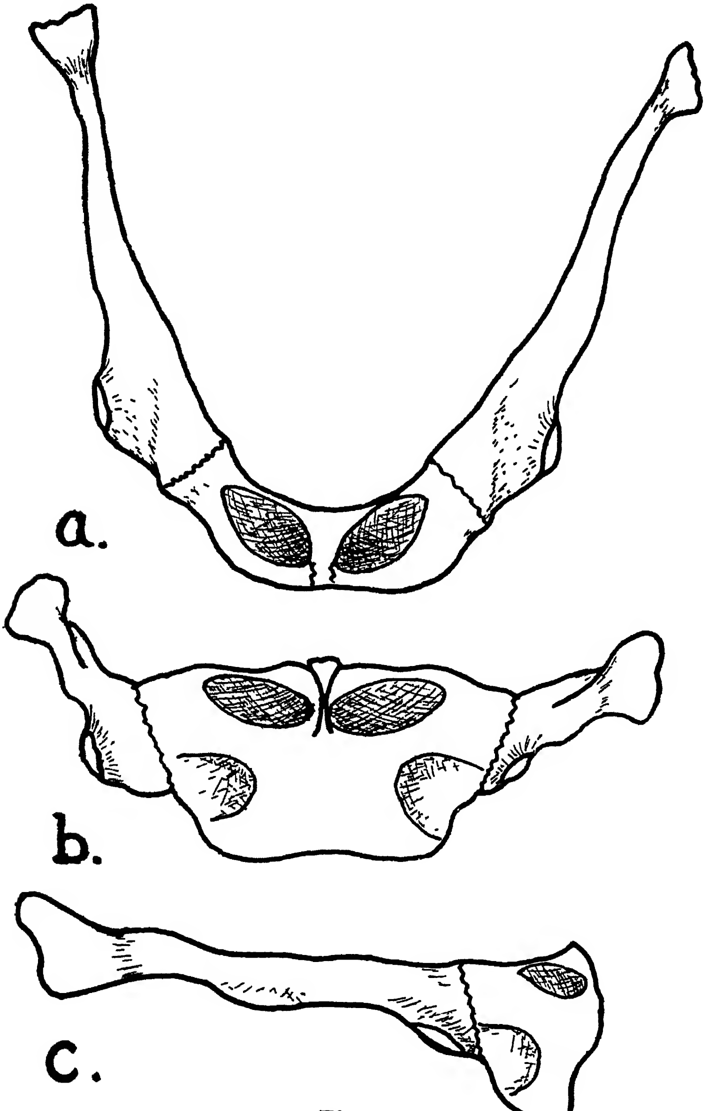

Fig. 1.
Bush Hyoid. Type 1. (M.M.K. 161). 2 × Natural Size.

The small size of the Zitzikama hyoid bone is easily recognised. It is, however, sturdily built on the whole.

The hyoid bone is much larger and more heavily built in the South African Negro. It is even larger in the case of the Mapungubwe race, in which it is also very powerfully constructed.

It seems that in European types the hyoid is usually sturdily built and not very large, and there is evidence that it varies to some extent as regards shape and size.

(b) *The Body of the Hyoid.*

Bush Hyoid.—The body of the hyoid is considerably better developed and has a completely different shape in the Type 1 Bush hyoid (M.M.K. 143, 161, 166, Fig. 1) than in the Type 2 Bush hyoid (Fig. 2). The anterior surface faces directly forwards

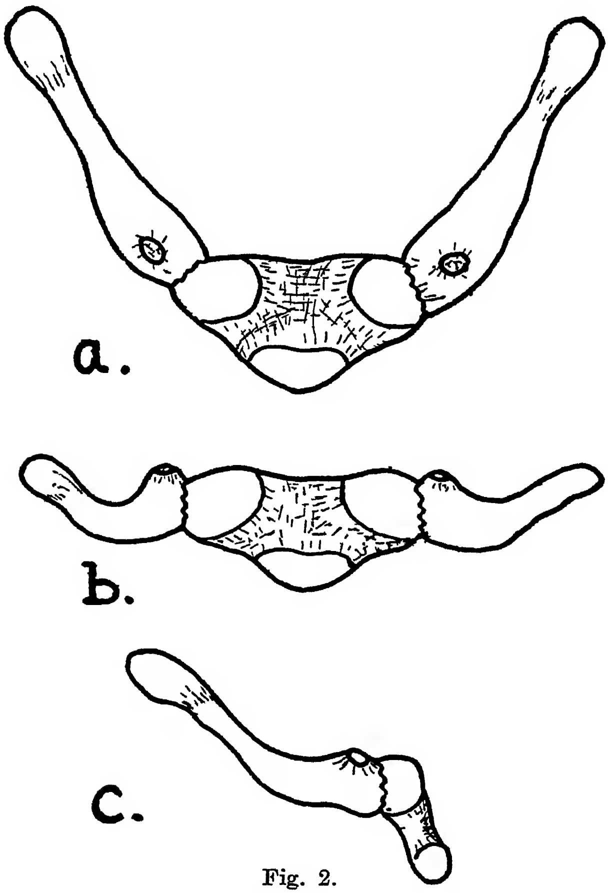

Fig. 2.

Bush Hyoid. Type 2. (M.M.K. 165). 2 × Natural Size

and is relatively smooth. The upper edge is on a level slightly higher than that of the greater cornua (Fig. 1, b), and the lower half of the body, to which the sterno-hyoid is ordinarily attached, projects downwards beyond the lower edges of these cornua so that a broad flange, which is almost as wide as the body, is produced. Two thickenings at the lower corners of this flange can be clearly distinguished when the body is viewed from below. The genio-hyoid insertions are elliptical in shape, relatively large. face upwards and forwards, are inclined at almost a right angle to one another, and are separated by a bony ridge which projects upwards between them, and the anterior end of which probably represents the attachment of the median mylo-hyoid raphe. There are no stylo-hyoid tubercles. The superior margin of the body presents a sharp edge, which is directed slightly backwards and upwards, and which, according to Parsons, serves as a line of attachment of the genio-glossus muscles, but to which the posterior fibres of the genio-hyoids are probably also attached. In M.M.K. 166 this sharp edge does not extend along the whole length of the body, for laterally, where the lesser cornua are attached, the superior surface of the body is rather flattened. The posterior surface of the body is concave, both transversely and vertically, and is quite smooth. It faces almost directly backwards.

In the remaining Bush hyoids (Fig. 2) the body is more or less flattened, and smaller in size. The anterior surface faces forwards and upwards in M.M.K. 174 and 165, and is slightly convex forwards in M.M.K. 151 and 144. This surface is covered with small tubercles and depressions. Three of these tubercles are especially well developed, and are situated respectively opposite the three corners of the body. The two at the lateral corners are the stylo-hyoid tubercles. The superior margin of the body is on approximately the same level as that of the greater cornua. Owing to the poor development of the omo-hyoid flanges of the greater cornua, the triangular sterno-hyoid flange of the body projects well downwards. In this group of hyoids, no depressions are left by the genio-hyoid muscles. It seems probable that these muscles were inserted above the stylo-hyoid tubercles on the superior surface of the body of the hyoid. There is no median ridge for the mylo-hyoid raphe. Indeed, a deep groove separates the stylo-hyoid tubercles. But it is possible that the mylo-hyoid raphe was attached to the inferior median tubercle on the anterior surface of the sterno-hyoid flange. The inferior margin is seen to be thickened when viewed inferiorly. The superior surface of the body is flat and broad, and there is no transverse mylo-hyoid ridge. Except in the case of M.M.K. 174, the posterior surfaces of the bodies are deeply concave, both transversely and vertically. These surfaces also face backwards and downwards, except in the case of M.M.K. 151, in which the posterior surface faces backwards and slightly upwards.

Zitzikama Hyoid.—The anterior surface of the body of the hyoid bone in the Zitzikama specimen (Fig. 3) is only very

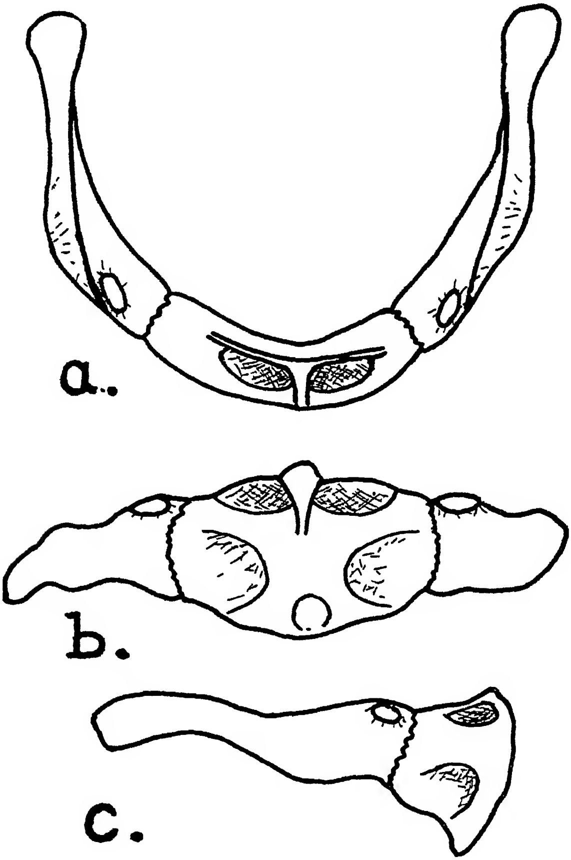

Fig. 3.
Zitzikama Hyoid. 2 × Natural Size.

slightly convex, almost smooth, and faces directly forwards. The impressions of the genio-hyoid muscles are well defined, oval in contour, with their broadest parts medially, face upwards and forwards, have their long axes in the same straight line, and are separated by a median bony ridge. There are no stylo-hyoid or mylo-hyoid tubercles. The superior margin of the body is represented in its intermediate half by a sharp transverse ridge mounted on a broad flat surface, which extends laterally beyond it to form the remainder of the superior surface. The inferior margin of the sterno-hyoid flange is thickened throughout. The posterior surface of the body is fairly markedly concave.

South African Negro Hyoid.—In this type the body of the hyoid (Fig. 4) is comparatively small, but it is strongly built and

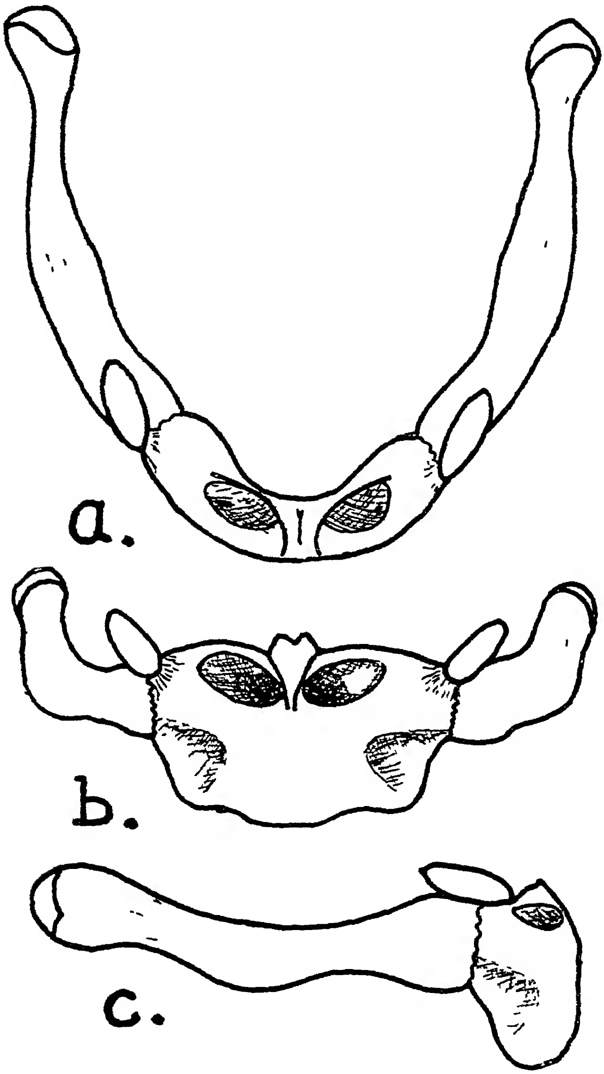

Fig. 4.
South African Negro Hyoid. 2 × Natural Size.

thick. While its posterior surface is deeply concave and smooth, the anterior surface is slightly convex and nodular. It faces directly forwards. The upper margin is raised slightly above the level of the greater cornua. The lower sterno-hyoid flange, which

is broad and powerfully developed, projects well downwards. The omo-hyoid muscles may occasionally find attachment to the lower lateral corners of this flange, which becomes well developed in these cases. The genio-hyoid impressions are large and broad, but are shallow, elliptical in contour, inclined at an obtuse angle to one another and separated by the low, broad, median ridge for the median raphe of the mylo-hyoid. There is no separate ridge for the mylo-hyoid muscle. There are slight stylo-hyoid tubercles infero-laterally to the genio-hyoid impressions, and the lesser cornua are mounted on tubercles immediately laterally to these.

Mapungubwe Hyoid.—The body of this type of hyoid (Fig. 5) is similarly characteristic in appearance. It is much longer than it is high, is rectangular in shape when viewed from the front, and evenly convex transversely. Its anterior surface is very nodular, shows no pronounced forward convexity, and faces directly forwards. Its upper margin is on a level with the greater cornua, and is straight. Only the lower third of the body projects downwards below the level of the inferior edge of the greater cornu as the sterno-hyoid flange. Its lower margin is slightly concave and is thickened at its infero-lateral corners. The genio-hyoid impressions are well developed. They are broadest and deepest infero-medially, owing to the presence of the prominent oblique mylo-hyoid ridges below them. They are oval in shape, face upwards and forwards, are inclined at an obtuse angle to one another, and are separated by a broad, well developed, median ridge. The upper margin of the body is sharp and is directed upwards and backwards. Conspicuous features of the anterior surface of the body are the prominent, thick ridges, which run obliquely downwards to the centre of the anterior surface, and which commence near the supero-lateral corners. They support the genio-hyoid impressions inferiorly, and form the upper boundaries of large, almost circular impressions which occupy the lateral halves of the body. If the mylo-hyoid and stylo-hyoid muscles were inserted along these ridges, it is likely that the omo-hyoid muscle secured an additional attachment to the body at the lateral circular impressions. The posterior surface of the body is flattened from above downwards.

European Hyoid.—In accordance with text-book illustrations (Fig. 6) the body of the hyoid is large, and tends to be rectangular in shape in the European race. It is apparently convex anteriorly in both the transverse and vertical diameters. Its anterior surface, which is nodular, faces forwards and slightly upwards. The upper margin is on a level with those of the greater cornua, and presents a median notch with a pair of lateral convexities. It is described in Quain's Anatomy as being relatively sharp. The sterno-hyoid flange is slightly developed though broad, and the inferior margin is relatively straight. The large, elliptical genio-hyoid impressions which are almost in the same straight line, and face upwards, forwards and laterally are

distinctive features. There is a broad, low, median ridge between them, which is continuous posteriorly with the relatively long transverse ridge, whose lateral ends nearly reach the slight tubercles for the lesser cornua. The stylo-hyoid and mylo-hyoid insertions are only slightly indicated. The posterior surface of the body is more concave in the vertical than in the transverse direction, and it faces downwards and backwards.

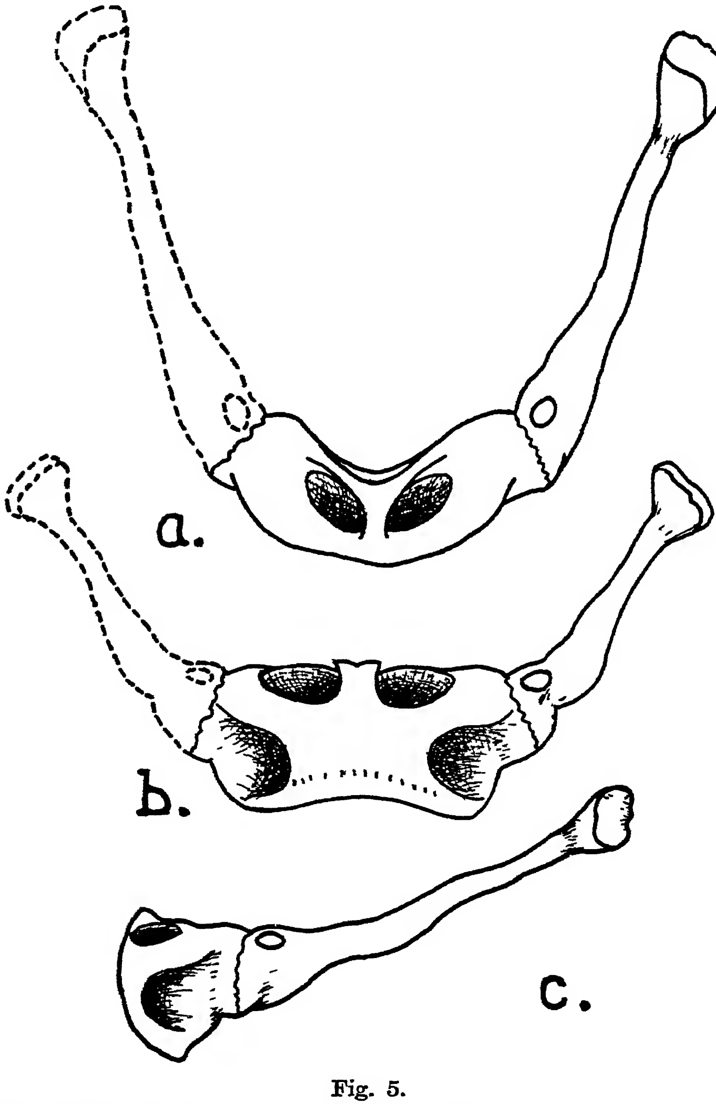

Fig. 5.
Mapungubwe Hyoid. (M. 5. Sceptre Skeleton). 2 × Natural Size.

(c) *The Greater Cornua of the Hyoid.*

Bush Hyoid.—The greater cornua vary in length in the Bush hyoid (Figs. 1 and 2), but are always proportionately longer than the body of the hyoid. They are usually slenderly built, particularly posteriorly. Their tips are usually damaged. M.M.K. 143 is intact here, and the cornua end in large, almost globular tubercles, which project upwards, backwards and medially. These tubercles are mounted on terminal expansions of the greater cornua, from which they are, however, clearly demarcated by means of slight circular constrictions. With the exception of M.M.K. 166, similar tubercles might easily have been present in the case of the other hyoids which have been damaged. M.M.K. 166 is distinctly different in possessing thickened sturdy, rounded ends with no flattening from within outwards.

Part of the intermediate half of each greater cornu is constricted and cylindrical and is frequently hollow. M.M.K. 151 is, however, medio-laterally flattened throughout. Towards the free end there are slight uniform expansions, to which the terminal globular tubercles are attached in M.M.K. 143. Anteriorly, the processes are sturdier and flattened from within outwards. The inner surfaces face slightly upwards posteriorly, and downwards anteriorly, for the greater cornua are twisted on themselves to a marked degree.

Except in the case of M.M.K. 151, a sudden vertical widening with the production of two distinct flanges on the inferior surface of each cornu occurs immediately anterior to the cylindrical part. These flanges represent the insertions of the thyreo-hyoid and omo-hyoid muscles respectively. In M.M.K. 143, 161 and 166, both the thyreo-hyoid and the omo-hyoid flanges are well developed, the latter being the larger and everted (Fig. 1). In the remaining Bush hyoids, this anterior flange is less conspicuous.

Zitzikama Hyoid.—The greater cornua of this hyoid (Fig. 3) are short and fairly sturdily built throughout. Posteriorly, each is slightly expanded medio-laterally, and thus becomes cylindrical. They are sharply truncated here, and the appearance is as if an articulation with some other bone was present originally. There is some slight medio-lateral constriction immediately anteriorly to the terminal cylindrical parts, so that the cornua are flattened. These cornua are not twisted on themselves, and their internal surfaces face medially and downwards along their whole extent. The vertical expansion commences relatively far posteriorly. Only the posterior thyreo-hyoid flange is well developed and everted, and is situated opposite the middle of the greater cornua.

South African Negro Hyoid.—The greater cornua tend to be rather short and powerfully constructed (Fig. 4). They are flattened medio-laterally throughout almost the whole of their

length, for even the terminal expansions are so flattened. There is no longitudinal twisting, and the inner surfaces face medially and downwards. The tips or terminal expansions of the greater cornua are thickened and rounded, and do not end abruptly. They point directly backwards and upwards. The posterior thyreo-hyoid flanges of the inferior borders of the greater cornua are best developed. They show no true eversion. Anteriorly to these flanges, at the sites of insertion of the anterior bellies of the omo-hyoid muscles, the heights of the greater cornua may even be less than at the thyreo-hyoid flanges.

Mapungubwe Hyoid.—The greater cornu is very long and almost straight and is directed upwards, backwards, and outwards (Fig. 5). While slightly flattened medio-laterally it is comparatively thick throughout, and is thus almost cylindrical

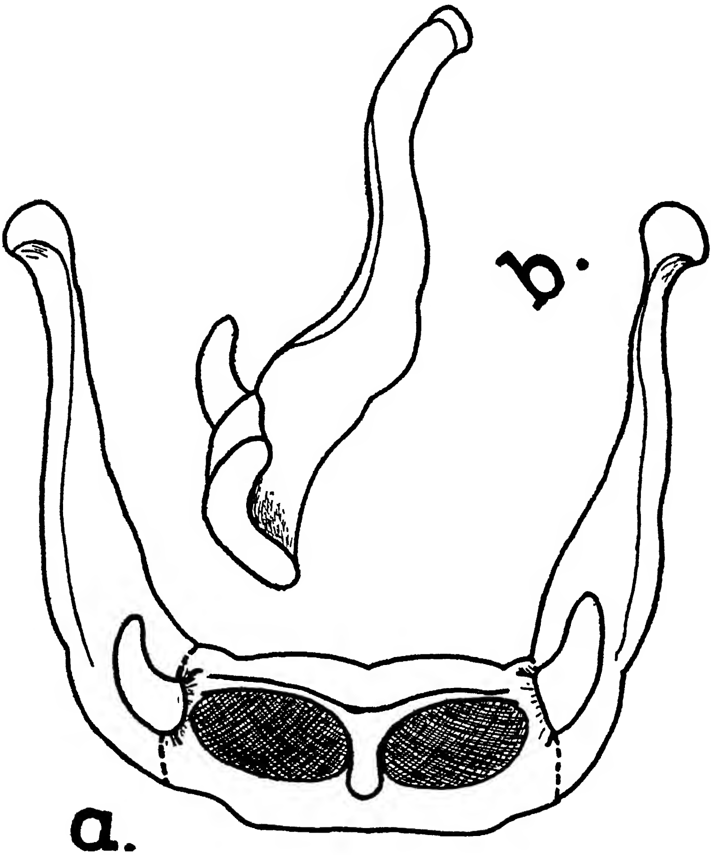

Fig. 6.

European Hyoid. (After Spalteholtz). 2 × Natural Size.

posteriorly. The flattened medial surface faces downwards and medially. The terminal expansion is very large and club-shaped, being thickened in all directions, but particularly transversely. Its tip is incomplete, the thyreo-hyoid insertion is represented by a slightly developed broad flange posteriorly, and anteriorly by a shallow elongated impression, which lies slightly medially to the inferior margin of the anterior quarter of the greater cornu. A poorly developed omo-hyoid flange, which encroaches to some extent on the joint, overhangs this impression. On the lateral aspect of the posterior two-thirds of the greater cornu, the line of origin of the hyo-glossus muscle is represented as a shallow groove. The greater cornu is also considerably thickened medio-laterally in its anterior fifth.

European Hyoid.—As can be determined from text-book illustrations (Fig. 6), the greater cornua are comparatively long. Their anterior two-thirds are massive, while the posterior thirds are much more slender. While they are generally depicted as being curved in the vertical direction, their axes are directed backwards and upwards. In Quain's Anatomy they are shown to be straight. There is generally considerable medio-lateral flattening, which involves their whole length. They are attached to the body in such a way that the flattened inner surfaces generally face downwards as well, and frequently the flattening appears to have occurred from above downwards (Cunningham's Anatomy). The tips are usually slightly expanded and rounded. In the case of the specimen depicted in Fig. 6, a well developed ridge for the origin of the hyo-glossus muscle is present. The posterior thyreo-hyoid flange tends to be better developed than that for the omo-hyoid, and may be considerably everted.

(d) *The Lesser Cornua of the Hyoid.*

Bush Hyoid.—The lesser cornua of the Bush hyoid are not always present, and some times occur on one side only. The sites at which they are united to the rest of the hyoid are also variable. They are entirely absent in M.M.K. 143 and 161. In M.M.K. 144 the left is present, being attached to the anterior end of the greater cornu. The right lesser cornua are present in M.M.K. 165, 174 and 151, being similarly attached to the anterior ends of the corresponding greater cornua. In M.M.K. 166 both are present, and are attached to the extremities of the body of the hyoid instead of to the greater cornua.

In structure, the lesser cornua range from slight tubercles to sharply pointed spicules of bone which may reach two to three millimetres in length. They are directed forwards, upwards and laterally. In M.M.K. 166 they are globular in shape. In M.M.K. 155 they must have been relatively well developed, as is evident from the appearance of the articular facet.

South African Negro Hyoid.—The lesser cornua are usually well developed, but they vary considerably in size. Generally they are spindle-shaped, and four to six millimetres in length.

They are mounted on small tubercles at the supero-lateral extremities of the body (Fig. 4). Their long axes are orientated upwards and backwards, and only slightly outwards.

European Hyoid.—The lesser cornua are generally well developed, and may reach six to eight millimetres in length. Occasionally ossification of the stylo-hyoid ligament occurs at its attachment to the lesser cornua, which may then give an erroneous impression of greater size. They are stated to remain cartilaginous for a variable period (Bruni, 9th to 10th year; Parsons 14th year), and may occasionally not ossify (Parsons, Spalteholtz). When present (Fig. 6) they are usually attached to the upper lateral corners of the body of the hyoid, being mounted on slight tubercles. They are so orientated that they point upwards, backwards and slightly outwards.

(e) *Mode of Union of the Body, the Greater and the Lesser Cornua.*

Bush Hyoid.—Some variation occurs in the mode of union of these different parts of the bone, which develop from separate ossification centres. Thus, whenever they are present, the lesser cornua are, except in the case of M.M.K. 151, always fused with the rest of the hyoid. In M.M.K. 151 there is a well defined smooth articular facet on the anterior end of the right greater cornu, which may be for the articulation of the lesser cornua which are missing.

The manner in which the greater cornua and the body are united is more variable. In M.M.K. 166 there is complete fusion, no trace of a joint being left. In M.M.K. 144, 161 and 174 slight circular grooves are left at the seat of union, and in M.M.K. 151 a deep cleft is present. The union must have been even less complete in M.M.K. 165 and 143, judging by the fact that the greater cornua had been detached during handling without producing the usual jagged ends which occur with true fractures.

Zitzikama Hyoid.—In this specimen the lesser cornua had apparently not been wholly attached to the body. They were attached to the anterior ends of the greater cornua immediately adjacent to the joints between these and the body. Small tubercles at these sites (Fig. 3) indicate that they were so orientated that they pointed upwards, forwards and outwards. The greater cornua are completely and firmly united to the body, but the line of union can be clearly distinguished.

South African Negro Hyoid.—The manner in which the various parts are united with one another varies with the age of the individual. In young adults plates of cartilage intervene between the greater cornua and the body, and the lesser cornua are attached to the body (Fig. 4) near the joints with the greater cornua by means of true diarthrodial joints. As age advances the cartilaginous plates become calcified, and bony ankylosis also occurs in the diathrodial joints between the lesser cornua and the body of the hyoid.

Mapungubwe Hyoid.—While the right greater cornu has been lost owing to the fact that it had merely articulated with the body, the joint between it and the left greater cornu has undergone firm ankylosis inferiorly, but a distinct gap is still present superiorly.

The lesser cornua were attached to the greater cornua at their junction with the body, and may have encroached to some extent on the joint. There is a smooth circular facet three millimetres in diameter, but no tubercle.

European Hyoid.—Various text-books state that the lesser cornua are united to the body by means of true diathrodial joints, and that ankylosis of these seldom occurs. Parsons claims, however, that in a series of a hundred and eight hyoids examined by him there was no incidence of a synovial joint between the lesser cornu and the body. The greater cornua are united to the body by means of intervening plates of cartilage. These disappear at middle age, and firm osseous union takes their place.

2. *Contours.*

Bush Hyoid.—The contours of the two groups of Bush hyoids are vividly contrasted in Figs. 1 and 2. Fig. 1 was drawn from M.M.K. 161 and Fig. 2 from M.M.K. 165.

Viewed superiorly, the general contours in these Bush types are *V*-shaped, but the limbs of the *V* in Type 1 diverge less and are longer than in Type 2. The apex in Type 1 is rounded on account of the transverse convexity of the body of the hyoid, whereas that of Type 2 is truncated as the body is flattened. In the latter type the internal and external dorsal contours are roughly similar, although the latter has a pointed apex on account of the conformation and orientation of the body of the hyoid. In Type 1, on the other hand, the lateral projection of the mylohyoid flanges and the flattening of the anterior surfaces of the body cause the external contour to be almost *U*-shaped. The expanded truncated tips of the elongated, slender greater cornua in Type 1 are sharply contrasted with the rounded tips of the relatively shorter and considerably sturdier greater cornua of Type 2. The presence of the tubercles to which the lesser cornua were attached is a further distinguishing feature. The appearances of the body of the hyoid are entirely dissimilar. In Type 1 the superior surface of the body is seen, and it presents a more or less anterior convexity and a posterior concavity. The large elliptical genio-hyoid impressions are visible. Owing to the orientation of the body in Type 2, on the other hand, its anterior surface is seen in this view. Its contour is roughly triangular, with the base posteriorly and the apex inferiorly. The large lateral stylo-hyoid and mylo-hyoid tubercles, the absence of the genio-hyoid impression, the substitution of a groove for the median bony ridge (of Type 1) and the presence of the tubercle on the apex are distinguishing features.

From the anterior aspect, many of the above features are seen. In addition, the following are observed. The body is proportionately larger in Type 1 than in Type 2. Its shape is that of a trapezoid in Type 1, the broadest part being superiorly. As the anterior surface of the body is viewed obliquely in Fig. 2, its shape is more pentagonal than triangular. The tubercles for the lesser cornua are raised above the upper margin of the body, which again has two lateral convexities. In Type 1 the upper margin of the body is slightly convex and the lower slightly concave.

In Figs. 1 and 2, c, the lateral contours are given. As the greater cornua diverge to an excessive degree in Type 2, the bone is proportionately much foreshortened. The greater cornu is straight and directed backwards. Owing to its medio-lateral flattening it appears broad from this aspect, as compared with its appearance in Fig. 1, a. Its tip is considerably expanded, also in a vertical direction. As the omo-hyoid flange is everted (Fig. 1, a and b), the greater cornu does not appear as broad anteriorly as was suggested from the contours of the other aspects. In Type 2 the greater cornu is sinuous in lateral contour, and its posterior half is directed upwards and backwards. The diameter of its anterior half is approximately the same as the corresponding diameter in Fig. 2, a. The considerably larger size of the body of Type 1 is emphasised in Fig. 1, c. Its anterior contour is sinuous. In Fig. 2, c, the antero-posterior flattening and the oblique orientation of the body with reference to the greater cornu are well illustrated.

Zitzikama Hyoid.—The contours of this hyoid are given in Fig. 3. The internal and external dorsal contours are horseshoe shaped. The tips of the relatively short and sturdily built greater cornua are rounded and of approximately the same shape as in the Bush hyoid, Type 2. The thyreo-hyoid flanges are slightly everted and the omo-hyoid flanges are not visible. Of the body only the upper surface is visible, and it is evenly convex forwards in the transverse direction. The genio-hyoid impressions are approximately in the same straight line and are relatively smaller than in the Bush hyoid, Type 1. The presence of the transverse ridge is indicated.

The shape of the body when viewed anteriorly (Fig. 3, b) is roughly elliptical; the upper margin is convex and projects upwards above the level of the greater cornua; the similarly convex lower margin projects downwards below the inferior margin of the greater cornua. The mylo-hyoid ridge is as well developed as in Bush hyoid, Type 1, but there are no lateral stylo-hyoid and mylo-hyoid tubercles. The greater cornua project directly laterally, and the sites of attachment of the lesser cornua are indicated.

Viewed laterally, the inclination of the axis of the body to the axis of the greater cornu is such that less than a right

angle is made between these inferiorly. The relatively large size of the body is evident even from this aspect. Its anterior contour is convex forwards. The greater cornu is sinuous in contour, but its posterior half is directed backwards and slightly downwards. The marked anterior inferior convexity occurs at the thyreo-hyoid flange. The tip of the greater cornu appears slightly truncated from this view and is not excessively expanded in the vertical direction.

South African Negro Hyoid.—The dorsal, anterior and lateral aspects of this hyoid are given in Fig. 4. The features of the contours of these aspects which characterise this type are the following:—The external and internal dorsal contours are more or less horseshoe shaped, the external being more so than the internal. The greater cornua are slightly convex outwards. They are almost the same width throughout, although some constriction precedes their rounded posterior terminal expansions. This is due to the fact that the cornua are so orientated that their inner flattened surfaces face medially and downwards. There is no widening of the cornua anteriorly to represent the omo-hyoid flanges. The lesser cornua are mounted on small tubercles at the lateral ends of the body of the hyoid. They are elliptical in contour, and are directed backwards and laterally. The body of the hyoid is curved throughout, but its posterior concavity is greater than the anterior convexity. The genio-hyoid impressions are relatively small and well separated.

The shape of the body when viewed anteriorly (Fig. 4, b) is that of a broad rectangle, the lower half of which projects downwards beyond the inferior margins of the greater cornua as the sterno-hyoid flange, which is almost as broad as the rest of the body. The upper margin of the body is slightly raised above the level of the greater cornua and concave at its middle. The broad median ridge projects upwards at this concavity. The inferior margin is on the whole convex downwards. The genio-hyoid impressions also face forwards. The mylo-hyoid ridge is more prominent and the stylo-hyoid tubercles better developed. The lesser cornua are observed to be directed outwards also. While the first parts of the greater cornua are inclined outwards, the posterior halves are directed upwards.

The upward curvature of the greater cornu as seen from the lateral aspect is responsible for the contours of the greater cornua described above. The terminal expansions are greater in the vertical direction, but this feature is masked by the fact that the cornua remain practically the same width throughout. The thyreo-hyoid flange is situated relatively far backwards. The lesser cornua are also elliptical in contour from this aspect. The great size of the sterno-hyoid flange can be recognised from this aspect owing to the convexity of the body.

Mapungubwe Hyoid.—The contours of the Mapungubwe hyoid (Fig. 5) are remarkably like those of the Type 1 Bush hyoid.

These contours are also comparable with those of the South African Negro hyoids.

The internal dorsal contour (Fig. 5, a) is, like that of the Type 1 Bush hyoid (Fig. 1, a), *V*-shaped with some degree of rounding of the apex of the *V*. The external dorsal contour similarly tends to be *U*-shaped on account of the widening at the anterior ends of the greater cornua. The greater cornu possesses a considerably transversely expanded tip, and the intermediate half of the cornu appears to be slender. The thyreo-hyoid and omo-hyoid flanges cannot be well seen from this aspect. The greater cornu is straight and directed outwards and backwards. The body of the hyoid is strongly curved in the transverse direction, and appears proportionately considerably broader than that of the Negro type. The deep, elliptical genio-hyoid impressions are almost at a right angle to one another and relatively close together.

The shape of the body from the anterior aspect is roughly rectangular, though actually it is hexagonal in shape with long upper and lower sides. The upper border is comparatively straight, and on the same level as the upper margin of the greater cornu. The lower margin is slightly concave, and the sterno-hyoid flange, though practically as broad as the rest of the body, consists of its lower third. The prominence of the mylo-hyoid ridge, stylo-hyoid tubercles and median ridge, and the depth of the genio-hyoid and the infero-lateral impressions of the body have been indicated. From this aspect it is also seen that the greater cornua project upwards as well as laterally and backwards.

From the lateral aspect it is seen that this orientation of the greater cornua can be ascribed in part to a slight degree of upward curvature. Its tip is expanded also in a vertical direction, and the height of the greater cornu is considerably reduced posteriorly. Both the thyreo-hyoid and omo-hyoid flanges can be distinguished, but these are not well developed. The pronounced forward curvature, the great size of the body, and the prominence of the ridges on its anterior surface can be recognised from this aspect as well. The body is seen to be convex forwards also in the vertical plane.

European Hyoid.—Both the internal and the external dorsal contours of the European hyoid bone tend to be *U*-shaped. In the specimen from which Fig. 6 was drawn, the internal contour is slightly more truncated anteriorly than usual, but the external contour is fairly characteristic. The large size of the rectangular body on which the large genio-hyoid impressions are present, the expansion anteriorly, and the posterior tapering of the greater cornua, and the large curved lesser cornua may be seen from this aspect.

The contours of the medial aspect of the right half of the hyoid are given in Fig. 6, b. The sinuous outline of the greater

TABLE I.—HYOID BON

MEASUREMENTS (in millimetres). INDICES (as percentages).	M.M.K. 166. Elderly Bush Female.	M.M.K. 161. Elderly Bush Male.	M.M.K. 143. Elderly Bush Male.	Average Bush Type 1.	M.M.K. 144. Young Adult Bush Female.
Maximal length of hyoid	36·0	43·0	38·0	36·8	28·0
Maximal breadth of hyoid	43·0	44·0	44·0	43·7	34·0
Breadth-Length Index of Hyoid	119·5	102·5	116·0	113·0	120·5
Length or greater cornua	31·0	37·5	35·0	34·5	27·5
Length of lesser cornua	2·0	—	—	2·0	2·0
Length of body	22·0	21·5	20·0	21·2	16·0
Length Index of body and greater cornua	71·0	57·4	66·7	65·0	58·2
Length Index of greater and lesser cornua	6·5	—	—	6·5	7·3
Maximal height of body	10·1	11·0	11·0	10·7	8·0
Minimal height of body	6·0	7·5	7·0	6·8	4·0
Index of minimal and maximal heights of body	59·5	68·0	63·8	63·8	50·0
Index of maximal height and length of body	46·0	51·2	55·0	50·7	50·0
Maximal height of greater cornua	6·0	8·0	6·0	5·8	4·1
Minimal height of greater cornua	3·0	2·5	1·5	2·0	2·0
Index of minimal and maximal heights of greater cornua ...	50·0	31·3	25 0	38·8	48·8
Maximal thickness of body	4·0	4·0	5·5	4·5	3·5
Index of maximal thickness and height of body	39·6	36·3	50·0	42·0	43·8
Maximal thickness of greater cornua	3·5	2·5	3·0	3·0	3·0
Minimal thickness of greater cornua	1·7	2·0	1·2	1·6	1·2
Index of maximal thickness and height of greater cornua ...	58·4	31·3	50·0	46·8	73·0
Index of minimal and maximal thicknesses of greater cornua	48·6	80·0	40·0	56·2	40·0
Greater cornu-body maximal thicknesses Index	87·5	62·5	54·6	68·2	86·0
Inclination of greater cornua to body	87·0°	85·0°	83·0°	85·0°	105·0°

E MEASUREMENTS AND INDICES.

M.M.K. 165. Young Adult Bush Female.	M.M.K. 174. Middle-aged Bush Male.	M.M.K. 151. Middle-aged Bush Male.	Average Bush. Type 2.	Zitzikama.	South African Negro [Male].	Mapungubwe Skeleton.	European [Spaltcholtz]	European Male [Morris].	European Female [Morris].	European Male (Av.) [Parsons].	European Female (Av.) [Parsons].
27·0	33·0	31·5	30·0	30·5	37·0	45·0	43·0	42·0	34·0	—	—
38·0	38·0	38·0	37·0	32·0	38·0	55·0	46·0	42·0	39·5	—	—
141·0	115·5	120·6	124·4	105·0	102·6	122·4	107·0	100·0	116·0	—	—
24·5	29·0	23·0	26·0	25·0	29·0	36·0	36·0	33·0	29·0	32·0	28·0
—	—	—	2·0	—	5·5	—	6·5	4·0	3·5	7·0	5·0
16·0	17·5	19 0	17·1	18·0	22·0	25·0	27·0	23·5	19·0	26·0	22·0
65·2	60·2	82·8	66·6	72·0	76·0	69·2	75·0	71·2	65·6	81·5	78·6
—	—	—	7·3	—	19·0	—	18·0	12·1	12·1	21·9	17·9
8·5	8·0	8·5	8·3	10·0	10·0	11·0	13·0	12·5	11·0	12·0	10·0
4·5	5·0	5·3	4·7	5·5	6·5	8·0	10·0	8·0	5·5	—	—
53·0	62·5	62·5	57·0	55·0	65·0	72·3	77·0	64·0	50·0	—	—
53·2	45·8	44·8	48·5	55·5	45·5	44·0	48·2	53·2	57·8	46·1	45·4
4·0	4·4	5·0	4·4	5·0	5·2	8·0	7·8	7·5	7·5	—	—
2·5	2·0	3·0	2·4	3·0	3·5	2·5	3·0	3·5	3·2	—	—
62·5	45·5	60·0	56·4	60·0	67·2	31·3	38·5	46·7	42·7	—	—
3·0	3·2	5·2	3·7	3·7	4·0	3·5	3·0	—	—	—	—
35·7	40·0	61·2	45·2	37·0	40·0	31·8	23·2	—	—	—	—
3·0	3·0	2·7	2·9	2·2	3·0	3·0	—	—	—	—	—
1·2	1·0	1·1	1·1	1·3	1·5	1·5	—	2·5	2·0	—	—
75·0	68·1	54·0	67·5	44·0	57·8	37·5	—	—	—	—	—
40·0	36·7	40·8	41·9	59·2	50·0	50·0	—	—	—	—	—
100·0	93·0	52·0	83·0	59·5	75·0	86·0	—	—	—	—	—
120·0°	105·0°	70·0°	100·0°	70·0°	85·0°	90·0°	105·0°	—	—	—	—

To face Page 345.

cornu from this aspect is very different from the almost straight appearance it has when viewed from above. In Quain's Anatomy, however, the cornu is shown to be straight also from this aspect. The expansion of its tip is observed to be also chiefly in a transverse direction. The upward and backward orientation of the greater cornu is well illustrated. The lesser cornu similarly projects well upwards and is curved also from this aspect. The genio-hyoid impression is not visible, owing to the fact that it faces forwards, upwards and laterally, and is obscured from view by the transverse and median ridges of the superior surface of the body. The vertical curvature of the body is quite obvious. The sterno-hyoid flange is evidently quite as thick as the rest of the body.

3. *Metrical Features.*

These have been assembled in Table 1, and the following facts may be observed:—

In regard to their dimensions and proportions, the three *Bush hyoids* representing Type 1 correspond very well, and it has been possible to prepare fairly representative averages for them.

The *Bush hyoids* constituting Type 2 are smaller in all their dimensions than those of Type 1. The angle of inclination of the body to the greater cornua is, however, considerably larger except in the case of M.M.K. 151, in which it is considerably smaller. Type 2 Bush hyoids are proportionately much broader and shorter than those of Type 1, the average breadth-length indices being 124 and 113 respectively. The body of the hyoid is proportionately higher (height-length index of the body), and the development of the sterno-hyoid flange (minimal-maximal body heights index) is proportionately greater in Type 1. The other main differences between these two types are: the smaller minimal-maximal height index of the greater cornu, its smaller minimal thickness and maximal height index, the smaller index of the maximal thicknesses of the greater cornua and body, and the smaller index of the minimal and maximal thicknesses of the greater cornua in Type 1 as compared with Type 2.

The dimensions of the hyoid bone of the *Zitzikama type* are on the whole comparable with those of Type 2 Bush hyoids. The body is, however, slightly longer than that of Type 2, and almost as high as that of Type 1. The angle of inclination between the body and the greater cornua is, moreover, considerably smaller than that of Type 1, and corresponds with the angle in M.M.K. 151. The breadth-length index (105) is much smaller than that of the Bush hyoid. There is also a greater difference between the maximal and minimal heights of the greater cornua. The index of the maximal thickness and height of the body and the index of the maximal thickness of the body and the greater cornua are correspondingly smaller. The length of the body, on the other hand, is proportionately greater with reference to that of the

cornua than in the Bush types. The indices of the maximal height and length of the body, the maximal and minimal heights of the greater cornua, and the minimal and maximal thicknesses are proportionately larger than in the Bush hyoids.

The *South African Negro hyoid* corresponds very nearly with the Bush hyoid Type 1 in respect of a large number of its dimensions. The lesser cornua are, however, considerably better developed and longer. The omo-hyoid flange is less developed, hence the high minimal and maximal heights index of the greater cornua. The greater cornua diverge less posteriorly, so that the breadth of the hyoid is less, and the breadth-length index (102·6) considerably smaller than that of the Bush hyoids. The greater cornua are also shorter than in the Type 1 Bush hyoids, and for this reason the length index of the body and greater cornua is considerably larger. The maximal height-length index of the body; the minimal-maximal thickness index of the greater cornua; and the greater cornu-body maximum thickness index are all larger than in the Bush hyoid, Type 1. The inclination angles of the greater cornua and the body correspond in the two types.

The Zitzikama and South African Negro hyoids have very little in common. The dimensions and indices are, except in the case of the breadth-length index of the hyoid, the index of the maximal height and length of the body, and the index of the maximal thickness of the cornua all larger than those of Zitzikama.

The larger size of the *Mapungubwe hyoid* is confirmed by the fact that with a few exceptions its absolute dimensions are greater than those of the two types of Bush, the Zitzikama and the South African Negro hyoids. The angle of inclination of the body and greater cornu is, except in the case of Type 1 Bush hyoid, greater than in the above types. The minimal heights of the greater cornua and the maximal thickness of the body are less than in the other hyoid bones.

While the measurements tend on the whole to be greater, the indices prepared from them are generally smaller than in the Bush, Negro and Zitzikama types. The length index of the body and greater cornua is greater than only that of the Type 1 Bush hyoid, and the index of the minimal and maximal thicknesses of the greater cornua is less than that of the Type 2 Bush hyoid. The index of the minimal and maximal heights of the body, and the greater cornu-body maximal thickness index are larger than in all these other types. The breadth-length index is approximately equal to that of the Type 2 Bush hyoid, and is therefore greater than in the other hyoid bones. The index of the minimal and maximal thicknesses of the cornua is equal to that of the South African Negro and is greater than that of the Type 2 Bush hyoid and the Zitzikama hyoid.

Such measurements as were permissible on the *European hyoids* figured in Morris's and Spalteholtz's anatomical text-

books agree fairly well with one another and with those recorded by Parsons. The female specimen drawn in Morris's text-book is on the whole smaller than the other specimens, though still consideraby larger than the smallest male or female hyoids measured by Parsons. Its maximal length measurement is particularly small, so that the breadth-length index is great, and even larger than that of the Bush hyoid, Type 1. The corresponding index of the other European hyoids is comparable with those of Zitzikama and the South African Negro type. In size the average male European hyoids may be compared with the Mapungubwe type, for it is nearly as large. The maximum dimensions recorded by Parsons even exceed those of the Mapungubwe type. Its maximal width is, however, considerably less even though greater than that of the other hyoid bones. The maximal and minimal height measurements of the body are greater than those of Mapungubwe. While the minimal height of the greater cornua is more than that of Mapungubwe, it is less than that of the South African Negro and the Zitzikama types. The inclination angle of the body and greater cornua is larger than the average for the Type 2 Bush hyoid, if M.M.K. 151 be included in this group. The maximal thickness of the body is the only measurement in respect of which it is smaller than any of the other hyoid types. The only indices which are similarly smaller are the minimal and maximal heights index of the greater cornua and the breadth-length index of the hyoid. All the other indices are either larger than those of the hyoids here described or may be compared with the corresponding indices of the Mapungubwe or the Type 1 Bush hyoids.

The European female hyoid tends to be smaller in the majority of its measurements than most of the other hyoids. The specimen figured in Morris's Treatise of Anatomy is smaller than the smallest hyoids measured by Parsons. Its maximal length and breadth measurements are larger than the Zitzikama and the Type 2 Bush hyoids, but smaller than in the other hyoids. Similarly, the length of the greater cornua is less than that of the Zitzikama specimen only, while the minimal height of the body is equal to that of the Zitzikama, and greater than that of the Type 2 Bush hyoids. The maximal height of the body is relatively great, and equals that of the Mapungubwe specimen. Only the length index of the body and greater cornua, and the index of the maximal height and length of the body are greater than those of all the other hyoids. The index of the minimal and maximal heights of the body is greater than those of the Mapungubwe and the Type 1 Bush hyoids, but smaller than those of other types.

Discussion.

It must be evident from the descriptions which have been given here that the hyoid bone of the Bush, Zitzikama, South African Negro, Mapungubwe and European races possesses in each case certain characteristic features. The information

assembled so far suggests that it may even be possible to determine the racial types, to which individual specimens belong, from an analysis of their morphological and metrical features.

The factors, which are responsible for the characteristic appearances of these hyoids, can by no means be easily decided on. While a larger skeletal element, such as the human skull, owes its variable shape and structure to a great extent to such factors as the different degrees of development of the brain, the changes in dentition, the effects of the maintenance of the erect attitude, etc.; and whereas the bones of the extremities are moulded by muscle traction or the various weight-bearing strains imposed on them in different postures, it would seem that the shape of the hyoid bone must solely or very largely be influenced by the traction effects of the numerous muscles attached to it. Where morphological differences exist in racial groups, these traction effects must be different, and this suggests, amongst other things, functional differences amongst these.

As has been shown, distinct types may be recognised in the case of the Bush hyoid. While M.M.K. 166 has been grouped with the hyoids of Type 1, with which it has most in common, it also differs from these in certain respects. M.M.K. 151 similarly has many features by means of which it is distinguished from the hyoids of Type 2. It is not necessary to recapitulate the distinctive features of the various hyoids to show that Type 1 has features in common with the Mapungubwe hyoid, and M.M.K. 166 has in addition features in common with the Zitzikama specimen. The hyoids of Type 2 have some features in common with those of Type 1 only, and with the exception of M.M.K. 151, which has many features in common with the Zitzikama type, are easily distinguished from the hyoids of other races.

The most decisive evidence in support of the conclusion, that these variations of the Bush hyoids, and their suggested affinities with the other racial types mentioned, are not merely attributable to some inherent and erratic variability of bone, but should be seriously considered as proof of hybridisation at least, is, that exactly comparable differences are present in the case of the mandibles of the corresponding Bush skeletons. (Schepers, 1934.)

In his reports on the Zitzikama skeletons Za. 1, Za. 2 and Za. 3, Laing (1924, 1925), concludes that certain skeletal material of this site (Za. 2) represents the pure or original San or Bush race. As has been stated previously no information is available as to the skeletal material, to which the hyoid bone, which is described here, belongs; but the majority of its features are so different from those of other hyoids, that it seems reasonable to conclude that the race to which it belongs is but poorly represented in or even very different from the admittedly mixed Bush race. It may even represent, as FitzSimons (1926) suggested,

the pure small race of survivors of the original ancient cave-dwellers of Europe.

The evidence of the hyoid bone of the Sceptre skeleton (M. 5) of the Mapungubwe site is entirely in agreement with that afforded by the rest of the skeleton. Its great size, massiveness, and tendency to form exostoses at muscular attachments are also completely in accordance with the similar features in the mandible of this individual. While the Mapungubwe hyoid has certain features in common with the South African Negro, it is also easily distinguished from it in respect of other features, some of which it shares with the Type 1 Bush hyoid. In my report on the mandibles of the Mapungubwe material (*vide* Galloway, 1937), I concluded that these corresponding features in the case of the Sceptre skeleton are, in all probability, Boskopoid in character. The Mapungubwe hyoid may thus, if this conclusion be correct, and until further information becomes available, be considered as the best, though not necessarily a pure representative of the Boskop racial type.

Little more can be said regarding the European hyoids, for, while abundant material should be available, the best descriptions which exist are apparently based on only a few specimens. That it possesses characteristic features must, however, be evident. But the limited material cannot possibly give an idea of the range of its possible variations. In the absence of such information, its racial relationships cannot be discussed satisfactorily. The two specimens figured in Morris's Treatise of Anatomy as representing the characteristic male and female hyoids, though roughly of the same shape, are of greatly different sizes. Such differences in size are also given by Parsons; but similar sex differences do not exist in the case of the Bush hyoids described here.

Summary.

The morphological and metrical features of seven hyoids of alleged known Bush origin, and of known sex, age, and geographical distribution are described. Two distinct types and also individual variations may be recognised amongst these.

The hyoids recovered from the Zitzikama and Mapungubwe deposits, and those of the South African Negro and the European races are described, and compared with the Bush hyoids and with one another.

The morphological features of the hyoid bone, which vary in different races, are the following:—(a) The presence or absence of the lesser cornua; their development and shape when present; their orientation with reference to and their mode and site of attachment to the remainder of the hyoid. (b) The length, general development and shape of the greater cornua; their orientation with reference to the body; the characters of their posterior terminations; the relative development of the flanges for the thyreo-hyoid and omo-hyoid muscles; and the mode of

union of the cornua and the body. (c) The shape of the body when viewed superiorly and anteriorly; its size; the direction in which its anterior and posterior surfaces face and the appearances of these; the development and characters of the sterno-hyoid flange, the mylo-hyoid ridge, the infero-lateral impressions, the median ridge, the superior surface, and the genio-hyoid impressions. (d) The contours of the hyoid as viewed from the dorsal, anterior and lateral aspects.

An analysis of the metrical data is supplied, and it verifies the evidence of the morphological features.

The hyoids of the different races discussed here have certain features in common, in such a way that racial affinities are suggested. Thus the evidence is, that the Bush race north of the Orange River, as represented by these specimens, is of mixed origin. This is in accordance with the views of Laing (1924, 1925) and Laing and Gear (1929). It is further confirmed by the information available regarding the corresponding mandibles. The Zitzikama hyoid type may be related to certain individual Bush hyoids, but is on the whole very different from the majority of these, being a very easily recognisable type. The Mapungubwe hyoid is related to the Type 1 Bush and the South African Negro, but also has distinctive features, which agree with the Boskopoid character of the mandible. The South African and the European hyoids possess very characteristic features.

The differences between these hyoids suggest differences of the functions in which they participate. The theory of miscegenation to account for the characteristics of the Bush and Mapungubwe hyoids seems most acceptable.

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A CONTRIBUTION TO THE PHYSICAL ANTHROPOLOGY OF THE OVAMBO

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The following study is the outcome of a visit to Windhoek in 1935, when the Municipality of Windhoek invited the University of the Witwatersrand to utilise the opportunity of the presence of members of an Ovambo tribe, the Ovakuanyama, at their Winter Show. To the Windhoek Municipality in general and Major Hahn and Dr. C. J. C. Lemmer in particular I am very grateful, because without their assistance I would not have been able to collect this material on fifty males and twenty females.

This analysis falls into two parts, non-metrical and metrical. For comparative metrical data Professor Dart has kindly allowed me access to his measurements and indices of the /'Auni and ≠Khomani Bushmen. I have also used my own data on the measurement of members of the Links tribe of the Korana Hottentots. Orford and Wells' study on a hundred South Eastern Bantu women and Schultze's Nama data have also been used.

I—Non-Metrical Features.

1. *Facial Type.*

In assessing facial types I have used the system of Orford and Wells (1937). To their classification I have added a Boskop facial type. Such a type is one which suggests an underlying facial skeleton of the Boskop type such as I have defined (p. 101 this Journal).

Only eight males and four females show the Negro facial type without admixture of other racial features. On the other hand, however, in only ten males and five females are the Negro features subordinate to facial types of other races.

The Bush facial type predominates in two males and one female, the Armenoid in five subjects (all male) and the Mediterranean in four (all female). Boskop and Mongoloid types each predominate in one subject, both male.

An arbitrary system of awarding points to each type according to its predominance was evolved. By this method the results in Table I were obtained. This table shows that the Negro and pre-Negro and Caucasian facial type predominance is approximately equal in both sexes. The Negro facial type obtains sixty

per cent. of the possible maximum occurrence; the pre-Negro obtains fifteen per cent., which is composed of twelve and a half per cent. Bush and two and a half per cent. Boskop in the male. while the female shows a straight fifteen per cent. Bush.

TABLE I.

Showing Percentage Distribution of Facial Types.

Type.	Male.	Female.	Total.
Negro	59·69%	60·83%	60·05%
Bush	12·40%	15·00%	13·23%
Boskop	2·33%	—	1·59%
Total pre-Negro	14·73%	15·00%	14·82%
Armenoid	14·34%	—	9·79%
Mediterranean	7·75%	22·50%	12·43%
Total Caucasoid	22·09%	22·50%	22·22%
Mongoloid	3·49%	1·67%	2·91%

Similarly the total Caucasoid twenty-two per cent. in the male is composed of fourteen per cent. Armenoid, and eight per cent. Mediterranean, while in the female it is entirely composed of Mediterranean. This almost sexual difference is corroborated by the findings of Wells and Orford, where of ninety-eight female subjects fifteen were Mediterranean and only one Armenoid, whereas in seven hundred and sixty male subjects, quoted by Dart (1937), the Armenoid preponderance completely outweighs the Mediterranean. This seems to suggest that in the intermingling of racial types, the masculine Armenoid facial type reveals itself in the Negro male while the more feminine Mediterranean type reveals itself in the female. This parallels Dart's findings in the Bush (1937) where the Boskop type of face is largely confined to the male and does not appear in the female.

2. *Skin and Eye Colour.*

A. *Skin Colour.* The skin colour ranges from 25 to 34 on von Luschan's scale. In forty out of fifty-eight subjects it ranges from 28 to 30. In eleven of the remaining eighteen it is 33·34. There is no sexual distribution. In the South-eastern Bantu female the skin colour ranges from 22 to 33, the majority of whom, however, are from 25 to 29, the most frequent colour being 28. In the Ovambo the colours most frequently occurring are 29 and 30, thus suggesting that the Western South African Negro is darker than the Eastern.

B. *Eye Colour.* Of the males, twenty-five have iris colour 2 of Martin's eye colour chart (i.e. brown), while seventeen have eye colour 1 (brownish-black). Of the females, on the other hand, seventeen have colour 2, and only two have colour 1, the

remaining subject having colour 4 (light brown). This suggests that in the Ovambo, the female iris has less pigment than the male iris, although no such corresponding difference is seen in the skin. Five males show *arcus senilis*, and two suffer from cataract.

The conjunctiva is predominantly light smoky in the male, half the subjects having this feature. Of the remainder, eighteen show a darker brown smoky appearance, while in five the conjunctiva is yellowish or yellowish-white. On the other hand, in sixteen of the females the conjunctiva is yellowish-white or yellowish; in only four has it a smoky appearance.

Ovambo men, therefore, seem to be characterised by a brown or brownish-black iris with a smoky conjunctiva, while the women have brown eyes with yellowish-white conjunctiva.

3. *Hair Type and Distrbiution.*

A. *Head Hair.* One-third of the men have pepper-corn hair which in almost every case is " skullcap " in distribution, that is, the anterior limits of the hair invade the forehead in an even curve without temporal recesses; this gives the appearance of a closely fitting skull-cap. Of the remaining subjects, who all have the typical Negro curly hair, two-thirds show a " skullcap " distribution, while the remainder have the typical Caucasian temporal recess. All the women have this " skullcap " distribution, while the proportion of curly to pepper-corn hair type is the same as in the male.

B. *Facial Hair.* (i) Eyebrows. Among the Ovambo it was noted that the eyebrows differed greatly in their distribution. In only twelve males and five females does the hair extend the whole length of the supraorbital margin as in the normal Caucasian; in seventeen males and nine females it extends from two-thirds to three-quarters of the length of the orbital margin; in another seventeen males and five females it extends halfway, while in four males and one female it only covers the medial third.

(ii) Beard and Moustache. Face hair is largely confined to the chin. Only seven have a European distribution of cheek hair, while a further nine have scanty tufts on the cheeks. In eleven subjects, all adult, there is no facial hair, and no evidence of their ever having shaved. In the remaining twenty-three the beard is confined to the chin.

On the whole, the moustache is scanty as compared with the European, although when a full beard occurs it is usually accompanied by a well developed moustache. A beard limited to the chin or a chin beard associated with scanty cheek hair tends to be associated with a sparsely distributed moustache; when the beard is absent, there is no evidence of a moustache.

These varieties of distribution of eyebrows, beard and moustache, may, over a large series of observations, be found to be of racial significance.

C. *Body Hair.* The Ovambo male and female are characterised by a sparseness of body hair. The hair is most constantly present in the axilla and over the pubes.

(i) Axilla. The hair of the armpit is straight in twenty-six of the males, curly in thirteen and pepper-corn in nine. In the remaining two subjects it is completely absent, while in all the male subjects its distribution is more scanty than is normal in Europeans. The armpit hair is straight in all the women, in two-thirds of whom it is very sparse.

(ii) Pubes. The distribution of European male public hair is in the form of a triangle, the apex of which reaches to near the umbilicus. The hair of the upper part of this triangle, that is, from about an inch above the symphysis pubis, is sparser than in the lower part. When this secondary sexual characteristic first appears in the adolescent it has a "female distribution," that is, it is limited to the immediate suprapubic region. Only later does it assume its triangular form.

In the Ovambo males, the pubic hair is "female" or "adolescent" in type in thirty-seven out of forty-six subjects in which this character was determined, the remaining nine having the typical adult male distribution of the European.

(iii) Trunk and Limbs. Hair on the trunk is wholly absent in thirty-six male subjects, in nine it is scanty, while only in four is there a European distribution. One individual has pepper-corn chest hair.

Hair on the arms is absent in forty-three and scanty in the remaining seven, while leg hair is absent in twenty-four, scanty in twenty-three, the remaining three showing European development. Hair on trunk and limbs, when present but not of European development, is of a downy infantile nature.

4. *Bodily Habitus.*

Whereas the male is characteristically hyposthenic or sthenic (thirty-seven out of fifty), the female is sthenic or sthenic-to-hypersthenic. Orford and Wells found that the Eastern South African Negro female is most commonly hyposthenic, but shows a greater proportion of hypersthenic subjects than is found in the European, the hypersthenic habitus being apparently associated with the unmixed Negro type.

Perhaps in a larger series, the same results would be obtained for the Ovambo women. At the most, however, in the small series at my disposal is can only be said that whereas these Ovambo individuals are predominantly hyposthenic or sthenic, those with a Mediterranean type of face have a greater tendency to hyposthenia.

5. *Steatopygia.*

Steatopygia appears to be a definitely sexual characteristic, since it is only present, and in small degree, in three out of fifty

males, while among twenty females it is slight in nine, and well developed in four, only seven showing no trace of this feature.

Of the three males showing steatopygia, two have a Bush element in their facial make-up, while the third has a Boskop element. In the women, however, there is no clear association between the presence of steatopygia and Bush facial type as found by Orford and Wells, although it is hinted at. Of the four women with Negro faces two have no steatopygia, while it is slightly developed in the other two. Of the ten showing a Bush element in their facial make-up five have slight steatopygia, while it is marked in one. The other three with marked steatopygia have a Mediterranean (that is female) facies. On the other hand, there are as many females with Mediterranean faces who have no steatopygia as there are with.

II—Metrical Analysis.

1. *Calvarial Indices.* (Table II.)

The cephalic index in the Ovambo male ranges from 68·9 to 83·5 with a mean of 75·8, while in the women the range is from 69·5 to 79·1 with a mean of 75·2. Both sexes are dolichocephalic and mesaticephalic in equal proportions (50 per cent. dolichocephalic and 40 per cent. mesticephalic). In the male series there are three hyperdolichocephals and two brachicephals, while among the women there is one hyperdolichocephal but no brachycephals. Approximately about two-thirds of the males and half the females lie between the range of 74 to 76.

When the Ovambo are compared with a series of two hundred and twenty-four Bavenda of both sexes, measured by Stayt (1931), although the means correspond, the Ovambo are seen to have a greater tendency towards mesaticephaly and a much less tendency to hyperdolichocephaly than the Bavenda. Brachycephaly is an equally sporadic occurrence in both. Dart (1937) in an analysis of a series of Eastern South African Negro males found that seventy per cent. or more were dolichocephalic again indicating a greater tendency towards mesaticephaly in the Ovambo.

The South Eastern Negro female series of Orford and Wells (1936) show the same degree of dolichocephaly as the Ovambo women, although they tend to be more hyperdolichocephalic.

These Ovambo values are at variance with the values got from a series of forty-nine Ovambo skulls. Here twenty-two per cent. are hyperdolichocephalic, fifty-one per cent. dolichocephalic and twenty per cent. mesaticephalic. However, when this Ovambo cranial index is compared with that of a similar series of Basuto and Zulu skulls, it is found that the Ovambo skull has a greater tendency towards mesaticephaly than the other two.

When compared with the Korana and the Bush, the Bush are seen to give much higher values while the Korana approximately correspond.

The fronto-parietal index in the male Ovambo has a range of 69·7 to 86·6, while the female range is from 73·3 to 87·7, with average values of 78 4 and 79·0 respectively. Two-thirds of the males and half the females lie between 76 and 81. In both sexes the forehead is thus relatively broad. In the male there is a tendency for the values of this index to form two groups, one around 76-77, the other around 81. The females have the same distribution, their higher average being due to a greater number of sporadic high values. The much higher values of the Ovambo compared with those of the Bush or the Korana is a reflection of the greater incidence of pentagonoid cranial form among peoples of the Bush physical type than among the Negro.

The fronto-biorbital index has a male range of 85·6 to 98·3 and a female range of 88·1 to 99·1, with a mean of 93 3 in both sexes. About three-quarters of the males and three-fifths of the females are grouped between 90 and 95. Again, there is a tendency for the values for this index to form two groups, one around 91 and the other at 94. These Ovambo values correspond closely to those of the Korana, but are definitely higher than those of the Bush. These high values indicate that the external angular process does not markedly project from the frontal region in the Ovambo. Further, they are an expression of the wide Negro frontal region compared with the Bush.

2. *Indices of the Face.* (Table II.)

The total facio-cephalic length index shows a marked sex difference in the Ovambo, which is reflected to a lesser degree in both the Bush and the Korana. In the male Ovambo it ranges from 53·2 to 73·4 with a mean of 61·3, while in the female it ranges from 51·7 to 61·2 with a mean of 56·3. Nine-tenths of the males gives values of 58 or over, while seven-tenths of the females lie below 58. The Bush values are consistently much lower than the Ovambo, revealing the foetal nature of the Bush skull. The Korana on the other hand, give values approximating the Ovambo female.

The upper facio-cephalic length index does not reveal the same sexual difference. This seems to suggest that the marked sexual difference in the total facio-cephalic length index is due to the sexual difference in the symphyseal height of the Negro mandible. The male range for this index is from 28·4 to 40·8, with a mean of 34·6, while in the female it ranges from 30·1 to 38·6, with a mean of 33·7. In both sexes this index clusters between 33 and 36. Below 33 there are nine males and seven females, while above 36 there are twelve males and two females.

The facio-cephalic breadth index has a male range from 80·0 to 102·8, and a female one of 87·8 to 102·4, the mean value in both sexes being 94·0. The majority of both sexes lie between 93 and 97; those with a Negro facies tend to have high values, while the lowest values are confined to individuals with a pre-Negro facial type.

The male range for the fronto-bizygomatic index is from 76·5 to 88·9 with a mean value of 83·1. In the female it ranges from 78·7 to 90·7 with a mean value of 84·0. There is a slight tendency for the values to be generally higher in the female, corroborating the suggestion of the somewhat broader female forehead. These individuals in which the Negro facial type predominates tend to have higher values.

The values for the bigonio-frontal index again indicate the somewhat wider female forehead. While the males tend to concentrate round the values 90 and 94 the females concentrate at 89 and 92.

The total facial index has a male range of 74·8 to 99·3 with a mean value of 83·8, while the female range is from 71·1 to 90·6 with a mean value of 79·7. There is a marked sexual difference in the facial length in that the female face is definitely shorter than the male. Three males and two males are hypereuryprosopic, twenty-one males and six females are euryprosopic, eighteen males and three females are mesoprosopic, four males and one female are leptoprosopic, while four males are hyperleptoprosopic. When compared with the South Eastern Bantu female, both Ovambo male and female are shorter faced. There the range is from 73·3 to 103·3 with a mean of 86·1.

The marked sexual difference seen in the total facial index is not so apparent in the upper facial index, owing to the greater mandibular symphyseal height of the male. Ten males and four females are hypereuryene, twenty-three males and eleven females are euryene, twelve males and five females are mesene, while five males are leptene.

The relation of upper facial length to total facial length seems to be approximately equal in all three groups, the only divergent values being those of the Ovambo females. This again corroborates the suggestion that the female Negro mandibular symphysis is shallower and probably more Bushlike than the male.

When these facial indices are compared with the Bush and Korana a marked difference is seen. The Bush face is definitely smaller than either the Korana or the Ovambo, who are in approximate agreement. This is instanced again when face lengths are compared to head length, where, except in the case of the total facio-cephalic length index the Korana values are less than those of the Ovambo. The bigonio-frontal ratio appears relatively constant in the three groups, but the fronto-bizygomatic ratio indicates a greater facial width for the Bush face, a width which gives this face type a pentagonoid outline as compared with the oval or almost rectangular Negro face.

3. *Indices of Facial Features.* (Table II.)

The interocular-biocular index shows that the interorbital region of the Ovambo female is somewhat narrower than the

male. This sexual difference is, however, not apparent in either the Bush or the Korana, in both of which groups the females have, if anything a wider interorbital region than the male. The Ovambo interorbital region is, however, narrower than that of either the Bush or the Korana. That this is not apparent in the external biorbital index may indicate the lesser degree of projection of the external angular process.

When the nasal length is compared with the bipalpebral breadth it is seen that the Ovambo and Korana females have relatively shorter noses than the males. This appears to a less marked degree in the Bush group. Relative to the biocular breadth the length of the nose is greatest in the Korana and least in the Bush, the Ovambo occupying an intermediate position, so that while the figures for the Ovambo males approximate to those of the Korana females, those for the Ovambo females are comparable to those for the Bush of both sexes.

The nasal indices reveal that the Ovambo nose is narrower and more projecting than that of any of the other groups. Although the Korana nose is as narrow or even narrower than that of the Ovambo, it is however, flatter, equalling in this respect the Bush nose. The nose of the Bush and Nama is broader and flatter than that of the Ovambo and Korana. The fact that in the Bush group there are several values of Negro dimensions need not indicate Negro admixture, but may be an indication of Mediterranean and Armenoid infiltration in the Bush.

When nasal depth is compared to width, the Ovambo nose again exceeds that of the other groups. The Korana approach more closely to the Ovambo than to the Bush, while the Nama nose is even more flattened than the Bush.

Stayt found in the Bavenda that the male length-breadth index ranges from 75·5 to 118·0, with a mean of 94·2, while in the female the range is from 71·8 to 121·7, with a mean of 88·3. For such an index these values closely parallel those of the Ovambo.

A comparison of the frequency curves for the mouth index of the groups reveals that in all three groups there is a tendency for this index to fall into two groups, one below 40 and the other above 40. Among the Ovambo there are more males in the lower group than in the higher, while the female values are the reverse. This is reflected in the means for this index. Approximately half the Ovambo are in each group, while the majority of the Bush fall into the upper group. Among the Korana, on the other hand, the greater number is in the lower group.

The values for the ear index show that the ears of the Ovambo and the Korana are of the same dimensions, but are broader relatively to their length than is the Bush ear.

4. *Stature and Limb Proportions.* (Table III.)

The mean stature for Ovambo males is 5 feet 7 inches, while the range is from 5 feet 1¾ inches to 6 feet 4½ inches. Even if

Cephalic I.	... ...	M.	.
		F.	.
Fronto-parietal I.	...	M.	.
		F.	.
Fronto-biorbital I.	...	M.	.
		F.	.
Total facial-cephalic L.I.	.	M.	.
		F.	.
Upper facial-cephalic L.I.	.	M.	.
		F.	.
Facial-cephalic B.I.	...	M.	.
		F.	.
Fronto-bizygomatic I.	...	M.	.
		F.	.
Bigonio-frontal I.	... ...	M.	.
		F.	.
Total facial I.	... ...	M.	.
		F.	.
Upper facial I.	... ...	M.	.
		F.	.
Index of facial lengths	...	M.	.
		F.	.
Bigonio-bizygomatic I.	...	M.	.
		F.	.
Interocular-biocular I.	...	M.	.
		F.	.
External biorbital I.	...	M.	.
		F.	.
Nasal L.-bipalpebral B.I.	.	M.	.
		F.	.
Nasal W.L.I.	... ...	M.	.
		F.	.
Nasal D.L.I.	... ...	M.	.
		F.	.
Nasal D.W.I.	... ...	M.	.
		F.	.
Mouth I.	... ...	M.	.
		F.	.
Ear I.	... ...	M.	.
		F.	.

Table II—Comparative Table of Means and Ranges of Head Indices.

OVAMBO.		S.E. BANTU.		BUSH (Dart).		NAMA (Schultze).		KORANA.	
Range.	Mean.	Range.	Mean.	Range.	Mean.	Range.	Mean.	Range.	Mean.
68·9— 83·5	75·8	—	—	69·4— 82·2	76·3	67·1— 78·5	72·9	69·1— 79·4	76·0
69·5— 79·1	75·2	67·2— 84·4	74·9	70·3— 80·6	76·6	—	—	69·4— 79·1	75·0
69·7— 86·8	78·4	—	—	69·0— 80·6	74·3	—	—	68·3— 82·5	73·4
73·3— 87·3	79·0	—	—	65·5— 75·2	71·5	—	—	68·7— 79·8	74·7
85·6— 98·3	93 3	—	—	84·3— 95·4	89·9	—	—	84·5— 99·2	93·4
88·1— 99·1	93·3	—	—	84·7— 97·1	90·6	—	—	91·0— 99·0	95·1
53·2— 73·4	61·3	—	—	50·8— 59·2	53·8	—	—	52·1— 66·0	57·3
51·7— 61·2	56·3	—	—	47·7— 54·7	51·9	—	—	48·1— 62·6	55·4
28·4— 40·8	34·6	—	—	25·6— 32·8	29·5	—	—	30·7— 37·8	33·3
30·1— 38·6	33·7	—	—	26·2— 33·7	29·1	—	—	27·2— 35·1	31·5
80·0—102·8	94·0	—	—	86·0— 99·3	92·2	84·5—102·9	94·0	81·6— 98·3	88·2
87·8—102·4	94·0	—	—	84·0— 94·9	88·6	—	—	79·3— 97·0	87·6
76·5— 88·9	83 1	—	—	74·3— 83·3	78·1	—	—	78·4— 91·2	82·8
78·7— 90·7	84·0	—	—	77·9— 87·7	81·2	—	—	80·2— 90·2	85·4
81·4—103·9	92·1	—	—	86·3—104·0	94·7	—	—	79·2—100·0	90·9
85·7— 99·0	91·4	—	—	71·9—100·0	89·9	—	—	80·4— 97·0	90·6
74·8— 99·3	83·8	—	—	66·2— 82·1	76·6	64·1— 96·2	80·6	78·0— 96·1	85·2
71·1— 90·6	79·7	73 3—103·3	86·1	69·4— 81·8	76·7	—	—	71·8— 95·0	84·9
42·3— 57·3	48·6	—	—	37·2— 51 5	42·6	—	—	45·4— 59·7	49·8
43·3— 52·8	47·9	—	—	37·3— 50·4	43·5	—		42·4— 54·1	48·3
49·6— 61·4	56·7	—	—	47·6— 62·2	55·0	—	·	52·2— 62·9	57·8
53·6— 64·8	60·0	—	—	52·1— 62·2	56·1	—	—	52·7— 67·0	57·0
69·9— 85·9	76·2	—	—	68·1— 82·0	74·7	62·5— 84·0	73·6	65·2— 82·3	75·2
70·6— 82·9	76·8	—	—	70·0— 82·4	73·3	—	—	70·1— 86·8	78·3
29·8— 43·6	37·8	—	—	26·1— 48·2	40·7	—	—	35·5— 42·4	39·2
28·7— 41·6	36·3	—	—	33·9— 46·7	40·8	—	—	31·5— 46·7	39·7
24·3— 38·7	32 1	—	—	21·3— 40·4	32·8	—	—	28·1— 36·1	31·8
28·7— 37·2	32·0	—	—	27·9— 38·4	33·5	—	—	26·6— 39·3	32·4
36·9— 56·4	46·2	—	—	33·9— 51·2	41·4	—	—	43·1— 60·7	52·3
36·9— 45·7	40·9	—	—	33·7— 51·5	40·0	—	—	42·7— 53·4	47·7
73·7—115·8	93·0	—	—	93·4—129·4	109·3	78·0—131·3	100·1	73·6—106·8	87·8
81·0—104·9	92·7	—	—	83·1—136·5	105·9	—	—	71·1—114·7	92·2
29·4— 53·8	42·5	—	—	21·2— 47·1	36·5	22·7— 39·4	30·6	23·5— 44·2	36·9
37·0— 56·1	46·4	—	—	20·5— 46·7	34·7	—	—	28·3— 45·9	35·6
31·9— 60·0	45·9	—	—	21·7— 43·8	33·9	20·5— 38·5	30·7	26·7— 53·7	42·4
41·5— 60·0	50·3	—	—	23·4— 43·6	32·9	—	—	25·5— 53·1	39·4
27·0— 51·8	40·0	—	—	22·6— 53·0	37·2	—	—	25·0— 57·1	39·1
32·7— 50·9	43·9	—	—	28·3— 51·3	40·4	—		23·8— 58·5	38·8
52·3— 74·5	62·3	—	—	36·5— 66·4	55·8	48·2— 73·2	59·1	55·9— 79·2	65·4
53·4— 66·7	61·5	—	—	47·5— 78·0	59·3	—	—	44·4— 66·1	54·5

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Stature in mm.	M.	.
	F.	.
Biacromio-stature I. ...	M.	.
	F.	.
Bitrochanteric-stature I. ...	M.	.
	F.	.
Intercristal-stature I. ...	M.	.
	F.	.
Arm-stature I.	M.	.
	F.	.
Leg-stature (cristal) I. ...	M.	.
	F.	.
Leg-stature (troch.) I. ...	M.	.
	F.	.
Arm-leg (cristal) I. ...	M.	.
	F.	.
Arm-leg (troch.) I. ...	M.	.
	F.	.
Intercristal-biacromial I. .	M.	.
	F.	.
Thoracic I.	M.	.
	F.	.
Ext. Conjugate-intercristal I.	M.	.
	F.	.
Interspinous-intercristal I.	M.	.
	F.	
Intercristal-bitrochanteric I.	M.	.
	F.	.
Bitrochanteric-biacromial I.	M.	
	F.	

TABLE III.—Comparative Table of Means and Ranges of Trunk Indices.

	OVAMBO.		S.E. BANTU.		BUSH (Dart).		NAMA (Schultze).		KORANA.	
	Range.	Mean.	Range.	Mean.	Range.	Mean.	Range.	Mean.	Range.	Mean.
..	1573—1941	1702	—	—	1441—1648	1556	1505—1761	1624	1512—1737	1604
..	1481—1687	1605	1453—1729	1574	1356—1594	1460	—	—	1431—1645	1531
..	20·2—24·1	22·1	—	—	20·1—23·8	22·1	—	—	19·4—23·6	21·6
..	20·1—22·9	21·8	18·7—24·3	22·2	18·9—23·0	21·6	—	—	19·8—21·4	20·6
..	15·6—18·1	16·8	—	—	15·6—19·4	17·6	—	—	15·6—19·2	17·1
..	16·2—19·0	17·4	16·7—25·9	19·3	16·7—21·4	18·9	—	—	—	—
..	13·8—16·1	14·7	—	—	13·4—16·9	15·0	—	—	13·2—16·5	14·5
..	13·5—15·8	14·6	14·1—20·7	16·2	13·8—17·4	15·8	—	—	—	
..	42·5—49·3	45·3	—	—	43·5—48·7	45·4	40·8—46·7	43·5	42·4—49·3	45·0
..	41·7—48·2	45·0	39·6—49·3	45·6	42·1—47·1	43·9	—	—	41·5—48·5	44·6
..	59·1—64·5	60·7	—	—	57·9—63·2	60·0	—	—	58·5—64·2	61·3
..	59·2—63·6	62·2	—	—	59·8—63·1	61·2	—	—	58·4—64·3	62·0
..	51·2—56·9	53·9	—	—	50·0—55·8	53·0	—	—	52·3—57·4	54·0
..	52·0—57·3	55·3	46·8—56·6	51·7	50·7—55·4	52·7	—	—	—	—
..	69·4—80·4	73·4	—	—	70·9—78·8	74·0	—	—	69·2—80·3	73·5
..	69·9—77·8	72·4	—	—	69·3—77·0	72·3	—	—	66·5—76·6	72·7
..	78·7—91·3	84·2	—	—	79·1—91·2	85·4	—	—	75·9—92·0	83·4
..	77·4—87·6	82·9	76·3—98·9	88·4	78·2—89·2	83·4	—	—	—	—
..	61·0—75·0	66·7	—	—	61·4—82·8	68·2	—	—	59·7—74·7	67·8
..	62·2—74·3	67·1	60·9—86·5	73·2	66·7—82·2	74·8	—	—	—	—
..	117·9—150·0	134·8	—	—	97·7—140·5	121·8	—	—	—	—
..	131·6—163·3	146·8	—	—	97·2—146·7	129·0	—	—	—	—
..	62·5—79·2	69·8	—	—	75·5—90·9	81·9	—	—	—	—
..	65·3—80·0	71·9	63·7—90·4	78·5	69·6—90·0	81·3	—	—	—	—
..	77·8—96·7	86·5	—	—	71·7—92·3	81·7	—	—	74·3—92·4	84·9
..	75·0—93·5	84·9	75·5—98·0	87·0	73·3—88·9	83·5	—	—	—	—
..	70·7—94·3	84·9	—	—	77·6—98·1	85·5	—	—	77·3—92·6	85·2
..	76·7—92·0	84·4	73·2—93·4	84·1	73·2—100·0	83·5	—	—	—	—
..	68·4—88·6	76·4	—	—	73·2—96·6	79·8	—	—	72·8—89·1	80·4
..	73·5—91·4	79·6	76·0—106·6	87·2	76·2—103·7	90·0	—	—	—	—

To follow Table II.

the very tall individual is excluded the mean is not appreciably affected. Half of the males lie between 5 feet 0¾ inches and 5 feet 8½ inches. Seligman (1930) gives the mean for several African Bantu groups as ranging from 5 feet 5½ inches to 5 feet 6½ inches, the average for all groups being 5 feet 5¾ inches.

The female Ovambo range is from 4 feet 8¾ inches to 5 feet 6½ inches, the mean being 5 feet 3 inches. Their values, however, are too scattered to indicate any grouping. Orford and Wells found that the range for the South Eastern Bantu women was from 4 feet 10 inches to 5 feet 8 inches, with a mean of 5 feet 2 inches. Stayt's Bavenda women had a mean of 5 feet 0½ inches, while the range was from 4 feet 7 inches to 5 feet 6 inches. The Ovambo, then, appear to be taller than any other South African Negro group.

An analysis of the ranges of the arm-stature index shows that, apart from the Bush females and Nama males, there is close approximation of values among the other groups. The minute differences in values for Nama males and female Bush is not sufficient to indicate any sexual or racial difference. It seems, therefore, that a mean value of 45 for this index is characteristic of African races. This is in accordance with Martin's values.

The leg-stature index has been determined by using both the trochanteric height and the height of the iliac crest. It is felt that the subcutaneous iliac crest will give more accurate values than the tip of the trochanter, which is more liable to be masked by overlying tissues. Further, the height of the iliac crest will give an indication of the sexual difference in pelvic height.

The values for the leg-stature (cristal) index shows a close correspondence between the respective sexes in each group. The females give higher values than the males. As such, while the index has no racial significance, it may have a sexual one.

The leg-stature (troch.) index has no such sexual significance. It is a fairly constant index for the males of the different groups, but the females show some divergence. The lower limb is much longer relative to stature in the Ovambo females as comcompared with South Eastern Bantu women. The Bush women take up an intermediate position.

Since the arm-stature index and the leg-stature (cristal) index have shown themselves to be so constant, it is only to be expected that the arm-leg (cristal) index should be equally constant. Further, this index, like the leg-stature index shows a slight difference, the arm being a trifle shorter relative to the leg in all groups. The arm-leg (troch.) index shows the same intergroup difference as does the leg (troch.)—stature index.

5. *Trunk Proportions.* (Table III.)

The biacromial-stature index shows practically no difference between the Ovambo, South Eastern Bantu and Bush groups.

The Korana are somewhat narrower across the shoulders than any of the other groups, but are not so narrow as the Heikum Bushmen (Werner, 1906). The bitrochanteric-stature index on the other hand reveals significant divergences. This index, in the first place, is appreciably higher in females than males. Among the males its values are much lower in the Ovambo than the Bush, the Korana taking up an intermediate position. Among the females, the Ovambo values are again markedly lower than are the Bush values, while the South Eastern Bantu women exceed the Bush. Werner's series of Heikum Bushmen are even narrower than the Ovambo.

Somewhat similar results are given by the intercristal-stature index, though the difference between the males of each series is not great. Among the females, the Ovambo group again give the lowest values and the South Eastern Bantu the highest, the Bush group occupying an intermediate position. While Werner does not give this index, it seems from his average measurements, that the indices for both sexes in his Heikum group must have been even less than the Ovambo. Herskovits (1930) gives for this index in the American Negro a value of 16·7, one which exceeds any African group studied by us. Although the range for the intercristal-biacromial index is from 61 to 75, over eighty per cent. of both sexes fall within the range of 61 to 68. There is a close correspondence between the Ovambo, both sexes, the Korana and Bush males on the one hand and the South Eastern Bantu and Bush females, who are in approximate correspondence, on the other.

Three-fifths of the male Ovambo give values for the bitrochanteric-biacromial index, which lie between 73 and 79 inclusive. Less than one-fifth are below 73, and slightly more than one-fifth are above 79. The values for the women are consistently higher. Both sexes give much lower values than the respective Bush sexes, while more than three-quarters of the South Eastern Bantu females gave between 79 and 95.

The intercristal-biacromial and bitrochanteric-biacromial indices reveal that the Ovambo male and female are narrower-hipped than are any other South African group. The Bush and Korana males are in essential agreement, but the Ovambo males are narrower than these other male groups. On the other hand the hip-breadth of the Ovambo female is markedly narrower than that of the South Eastern Bantu and Bush female. Although the Bush females have similar ranges to the South Eastern Bantu female their means are higher.

The thoracic index shows marked sexual and racial differences. Ten out of twenty Ovambo females form a definite cluster between the values of 143 and 150, the remainder being equally divided and sporadically scattered below and above these values. Only a quarter of them give values less than the uppermost limit of Bush female range of 140·5. The Ovambo males, on the other hand, have half their numbers grouped between the

values of 128 and 138. Eight out of fifty are grouped near the 150 value, while a fifth of them cluster around the Bush mean value of 121·8 for this index. The Bush and Ovambo female is flatter-chested than the male of the respective groups, while the Bush of both sexes are rounder-chested than any of the Ovambo women.

6. *Pelvic Proportions.* (Table III.)

In approximately four-fifths of the male Ovambo, the external conjugate-intercristal index lies between 66 and 73 inclusive, while half the females give values between 67 and 70. These female values are definitely less than those of the South Eastern Bantu females, where two-thirds give values between 73 and 85 for this index. There is a suggestion of the sexual difference in this index, the males giving slightly lower values. When compared with the Bush, however, there is a marked racial difference, since the range for all Ovambo is from 62 to 80, while for all Bush it is from 75 to 90.

The values for the interspinous-intercristal index in the Ovambo male tend to fall into three groups:—(1) 79-81, (2) 84-88, and (3) 92-93. Of these, the second group is the largest, and comprises almost half the males. Three-fifths of the females, on the other hand, give values between 80 and 84, that is, intermediate between the male groups 1 and 2. This is in sharp contract to the South Eastern Bantu women, of whom three-fourths fell within the range of 82 to 94. The Bush values of both sexes are less than those of any other group.

The intercristal-bitrochanteric index reveals neither racial nor sexual differences. It is approximately the same value for both sexes of all the groups.

These pelvic proportions reveal therefore that the Ovambo pelvis is flatter and more flared out than the pelvis of the Bush physical type, or the pelvis of the South Eastern Negro.

III—Facial Type and Facial Indices.

Even with such a limited series as these Ovambo individuals make, there are several indications of a possible correlation between facial type and facial indices, which, however, will require a much larger series for convincing proof.

To establish a basis on which to work, the absolute canial length was plotted against facial type The Bush, Negro and Mediterranean face types are found to be associated with short, medium and long skulls respectively. While a long skull need not be associated with a Mediterranean or Boskop facial type, these two facial types seem to be linked with a long skull. The upper- and total-facial cephalic length indices reveal that the Bush and Negro facial types occupy the central quartiles. Three-quarters of the individuals with a Negro facial type give values between 33 and 34 in the upper facial-cephalic index, while those

of the Bush facial type tend to cluster round 35. The range of the index is from 28 to 40. That both Negro and Bush facial types should be associated with the central quartiles suggests that an upper face with a length of thirty-three to thirty-five per cent. of the sephalic length is the relationship in a harmonious African skull. In a series of one hundred and fifty South African skulls, the peak value for this index is 35.

In both these indices, the individuals with Boskop facial type occupy the lower values, while the Caucasoid face type occupies the higher values. This suggests that the Mediterranean and Armenoid faces are longer relative to cephalic length than are the African face types. A face which is narrow relative to cranial breadth is usually of the Bush facial type, as would be expected from the foetal nature of the Bush skull.

The facial indices, upper face and total face, show that those individuals of the Mediterranean and Armenoid facial types tend to have longer and narrower faces than those individuals with African facial types. Out of twenty-five individuals of both sexes with a total facial index of 86 or more, twenty show Mediterranean or Armenoid features. This is reflected again in the upper facial index, where the proportion of Caucasoid to African face types in the mesene and leptene groups is three to one.

When the transverse diameters of the face are analysed, it seems that the Bush bigonial diameter tends to be relatively narrow, while the Caucasian tends to be wide. The frontal diameter is more frequently narrow in the Bush facial type than in any other. In the Caucasian facial type it tends to take up an intermediate position, while in the Negro face type it is wider than in the others.

IV—Habitus and Trunk Proportions.

Among this Ovambo group, there is evidence of the relationship between habitus and trunk proportions as Orford has found hinted at in the South Eastern Bantu. To arrive at any definite conclusion would require greater numbers, for to allocate seventy individuals into seven groups makes the sub-divisions too small to have any significance whatever. By reducing the habitus groups to two, hyposthenic or less, and sthenic or greater, and finding out where these two groups lie in the frequency curves of biacromial-stature index, intercristal-stature index and bitrochanteric-stature index, it is found that the hyposthenic individuals group round the lower values, while the higher values are occupied by the sthenic individuals. In every case the markedly sthenic individuals gave the highest values in both sexes.

In the case of the external conjugate-intercristal index, there is a definite tendency for the sthenic subjects to give higher values, that, is, the more the individual tends to hyposthenia, the greater the tendency towards a flattened pelvis. Again, the

higher values in the bitrochanteric-biacromial are occupied by sthenic individuals, indicating that in hyposthenic subjects the biacromial diameter is three-quarters or less of the trochanteric diameter.

The interspinous-intercristal and thoracic indices are interesting. The sthenic individuals tend to cluster in the two central quartiles of both indices, where the proportion of sthenic to hyposthenic individuals is two to one, while the two lateral quartiles are occupied by hyposthenic and sthenic individual in equal proportions.

Conclusions.

The Ovambo show six facial types—Negro, Bush, Mediterranean, Armenoid, Mongoloid and Boskop, in that order of frequency. The Negro and pre-Negro facial types occur with the same frequency in both sexes, although the individuals of Boskop facial type are male. The Mediterranean facial type is a more feminine characteristic than is the Armenoid. These facial types are associated with definite types of skulls and facial skeletons.

The skin colour is darker in the Ovambo than it is in the South Eastern Negro. Eye colour reveals a sexual difference, the male being characterised by a brownish-black to brownish iris, with a smoky conjunctiva, while the women have brownish irises, with yellow-white conjunctivae.

The head hair is characteristically curly and of "skull-cap" distribution. The eyebrows seldom extend the whole length of the supraorbital margin. The facial hair is largely confined to the chin, and if a moustache is present, it is seldom of European potentialities. Body hair is sparse. The male pubic hair has a "female" distribution.

The male is characteristically hyposthenic or sthenic, while the female tends to be sthenic to hyperosthenic. Habitus seems to have a definite relationship to trunk proportions. Steatopygia is a sexual characteristic, occurring much more frequently in the female than the male; when it does occur in the male it is associated with a Bush facial type.

The Ovambo head is dolicho- to mesati-cephalic, with a broad frontal region. There is little projection of the external angular processes. The male face is definitely longer than the female. The female has a narrower interorbital region than the male, while this region is narrower in all the Ovambo than it is in the Bush physical type. The Ovambo nose is narrower and more projecting than that of the Bush type.

The Ovanmo are taller than any other group of South African Negroes so far studied. The length of arms relative to stature seems to be constant for African races. The length of leg (that is the height of the iliac crest) is greater in Ovambo females than in males, while the trochanteric height shows that the female Ovambo leg is longer in relation to stature than in South Eastern Negro females. The trunk diameters of the Ovambo, when com-

pared with stature, are much narrower than those of the South Eastern Bantu. Thus the Ovambo are taller and narrower-hipped than any other group of South African Negro. The chest is flatter in the female than in the male, while the Ovambo group as a whole are flatter-chested than other South African groups. The pelvic indices show that the female pelvis is narrower, flatter and more flared out than in other South African Negro or Bush groups. Thus the Ovambo is characteristically taller, flatter-chested, and has a narrower flatter pelvic than the other South Eastern Bantu.

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THE STATUS OF THE BUSHMAN AS REVEALED BY A STUDY OF ENDOCRANIAL CASTS

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With 6 Text Figures.

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I—Introduction.

The expansion of the brain has always been recognised in general terms as one of the principal distinguishing features of man. Nevertheless, the Presidential Address delivered by the late Sir Grafton Elliot Smith to the Anthropological Section of the British Association in 1912, may be taken as marking an epoch in anthropological thought. The thesis of this address is that cerebral expansion has been, not merely a factor, but the prime determining factor, in human evolution. This concept is now accepted as an axiom of anthropological thought, and it is recognised that, in the final analysis, the status of any human type is to be determined, not by accidents of skull shape, but by the degree of cerebral development. Such a conception has contributed powerfully to the rise of a biological, as opposed to a purely morphological, approach to the problems of anthropology.

The comparative analysis of the brain, can, of course, only be carried out on extant types, and is affected further by the degree of ease with which specimens can be secured. It can, however, to a large extent be supplemented by a study of casts obtained from the interior of the brain-case. Of the factors which contribute to the modelling of this cavity, the brain is recognised to be by far the most important, so that unless some pathological hindrance to the free growth of the brain-case is imposed, the form of the cranial cavity is a true reproduction of the shape assumed by the expanding brain. Not only is the gross shape of the brain thus reproduced, but many of the major and even minor features of its modelling are imprinted on the internal surface of the cranium. No anatomist to-day supports the sceptical attitude of Symington regarding the interpretation of these features. The study of the endocranial cast has thus powerfully reinforced that of the living brain. This method is

all the more valuable, since it can be applied to the skulls of extinct as well as of living types of mankind. In the hands of Sir Grafton Elliot Smith and his pupils, of Sir Arthur Keith, of Professor R. Anthony and of Professor Ariëns Kappers, this study has been greatly developed.

It is true, as these anatomists fully recognise, that the endocranial cast reflects, besides the morphology of the brain, other features of the interior of the skull, such as the vascular channels and stream of cerebro-spinal fluid. All of these features, as Keith (1931) has remarked, must be in some way related to cerebral development even if the nature of the relationship is not at present clear to us. Their presence, however, tends to mask some of the features of the brain itself, and further to limit the direct comparison of the endocranial cast with the living brain.

Because of this, it is evidently desirable that in any study of the status of a human type as revealed by its brain development, comparison should be made with endocranial casts of these peoples, rather than with their actual brain. When the endocranial casts of extinct South African types are to be examined, as has been done by Dart (1923), Dreyer (1936) and Meiring (1936), as well as by overseas workers, comparison with the Bushman as the most ancient surviving South African type becomes important. Before such comparison can be made, the characteristics of the Bushman endocranial cast must themselves be defined.

Aside from this, however, the morphology of the Bushman brain is of the greatest significance for the light it throws on the status of this peculiar variety of humanity. In a recent memoir on the endocranial cast of *Sinanthropus*, Shellshear and Elliot Smith (1934) say: "We have selected the endocranial cast of a Bushman for comparison, because it appears to us that, from the known brains of Bushmen, this race shows a greater assemblage of primitive than is to be found in any other race." In the face of this strong expression of opinion, it is remarkable that no attempt has hitherto been made to supplement our limited knowledge of the Bushman brain by the study of a series of endocranial casts of this race.

The descriptions of individual brains of the Bushman given by Tiedemann, Marshall, Koch, Sergi and Rawitz, have been collated by Kappers (1929). More recently this material has been supplemented by the admirable account of three brains by I. Slome (1932). Still more recently, Shellshear (1934) has elaborately discussed the specimen described by Marshall in the light of more recent developments in the study of human cerebral evolution. These records with the cursory observations of the endocranial cast incorporated in the memoir of Shellshear and Elliot Smith, represent the sum total of our knowledge of the Bushman brain.

The present study is based on endocranial casts from eleven Bushman skulls, seven male and four female, of established authenticity. With the exception of one male skull, A. 26, presented to the Department of Anatomy, University of the Witwatersrand, by Dr. L. Fourie, all these belong to the collection of the MacGregor Memorial Museum, Kimberley. We are deeply indebted to Miss M. Wilman, Curator of that Museum, for the opportunity of examining these specimens and of securing this series of endocranial casts.

II—Metrical Analysis.

The metrical investigation of this series has followed the system elaborated by Kappers (1929). Certain additional observations have, however, been included; these, and the reasons for making them will be explained as the different groups of measurements are discussed. The observations on the individual specimens of the series are set out in Tables 1 and 2, while comparative data are assembled in Table 3.

These comparative figures have been drawn up from the papers of Slome on the Bushman brain, of Woollard (1929) on the Australian, and of Castaldi (1936) on the Bantu (Basuto) brain. Further I have taken from the work of Kappers (1929) figures for the dolichocephalic Dutch brain. The results of this author show a wide divergence between dolichomorphic and brachymorphic types of brain, so that, as Woollard has observed, "The Dutch brachycephalic brain is much more like the Chinese brain than it is like a Dutch dolichocephalic brain. Since, as will be shown below, the Bushman brain is characteristically dolichomorphic, comparison has been limited to the abovementioned dolichomorphic types.

Volume and Weight. Table 1 shows that the endocranial volume of these specimens ranges between 1,250 and 1,350 cc. for the males, and 1,000 and 1,150 cc. for the females. All are thus microcephalic. The mean values are: Male 1,281 cc., female 1,062 cc.

By the fomula employed by Kappers, the estimated weight of the brain ranges from 1,168 to 1,263 grammes in the males, and from 949 to 1,067 grammes in the females, the mean values being for the males 1,212 grammes, for the females 1,005 grammes. The formulae of Welcker and of Manouvrier, previously in use for this estimation, would give considerably lower values. Considerably lower weights have also been determined on the actual brain by Marshall, Koch and Slome. The last-named author concluded that "the weight of the Bushman brain is lower than that of any living race of man as yet recorded." From these observations, however, it is not clear that the average weight of the Bushman brain is less than that in the Australian aboriginal. which is given by Kappers as 1,196 grammes for males, and 1,123 grammes for females.

TABLE 1—GENERAL MEASUREMENTS AND INDICES OF BUSHMAN ENDOCRANIAL CASTS.

No.	Locality	Sex	Max. Length mm.	Parietal Breadth mm.	Temporal Breadth mm.	Frontal Breadth mm.	Encephalic Index	Fronto-Parietal Index	Fronto-Temporal Index	Volume cc.	Weight (Kappers) gm.
143.	Kuruman	Male	172	127	124	100	73·84	74·84	80·65	1242·5	1176
151.	Gordonia	,,	173	129	125	98	74·57	76·00	78·40	1296·25	1227
161.	,,	,,	170	124	122	98	72·94	79·03	80·32	1233·75	1168
163.	S.W.A.	,,	173	130	130	101	75·14	77·70	77·70	1335·0	1263
166.	,,	,,	163	126	127	97	77·91	76·99	76·38	1250·0	1183
175.	Bushmanland	,,	175	128	125	94	73·14	73·44	75·20	1283·75	1215
A26.	S.W.A.	,,	178	124	126	96	70·80	77·42	76·19	1326·25	1255
144.	Gordonia	Female	162	115	118	90	72·84	78·26	76·27	1066·25	1009
165.	,,	,,	163	126	127	93	70·56	73·81	73·22	1002·5	949
167.	,,	,,	162	120	120	89	74·07	74·17	74·17	1052·5	996
174.	Bushmanland	,,	164	125	128	96	78·05	76·80	75·00	1127·5	1067
	Male Average		172·1	126·9	125·6	97·7	74·05	76·49	77·83	1281·07	1212·4
	Female Average		162·8	121·5	123·3	92·0	73·88	75·76	74·67	1062·19	1005·25
	Total Average		—	—	—	—	74·00	76·22	76·68	1201·47	1137·09

The endocranial volume determined by Pittard on a large series of skulls, and the brain weight calculated by Kappers from his figures are much higher than those found in this investigation. It must be emphasised that the present series, though small, is composed of specimens of established authenticity, whereas that of Pittard is of heterogeneous origin. Results obtained by D. Slome (1929) upon material of historic Bushman origin are comparable with, or even less than, those of the present investigation.

It may be concluded that the volume and weight of the brain in the Bushman, if not less than those of the Australian aboriginal, are closely comparable to them. Further, the range of these characters in both these races is of the same order as has now been determined for *Sinanthropus* (Weidenreich, 1937).

The mean values obtained by Castaldi, viz., 1,215·6 grammes for ten male Basuto, and 1,165·0 grammes for four females, are also deserving of remark. These figures would indicate that the weight and volume of the Bantu brain are very little greater than those of the Bushman, whereas it has been generally held that the endocranial volume of the Bantu appreciably exceeded that of the Bushman. It seems, however, that Castaldi's series of brains was in this respect atypical. My own observations on Bantu brains of various tribes have yielded an average of 1,348 grammes for thirty-two males and 1,249 grammes for fourteen females. This result agrees better than that of Castaldi with estimates based on the measured cranial capacity of Bantu skulls. In spite of Castaldi's results, then, it may be accepted that the Bantu brain is heavier and of greater volume than that of the Bushman.

Encephalic Index. (Table 1.) This index ranges from 70·80 to 77·91 in the males, and 70·56 to 78·05 in the females, the average of the two sexes being 74·05 and 73·88 respectively, and that for the whole series 74·00. According to Castaldi indices below 79 are classed as dolichencephalic, between 79 and 84 as mesencephalic, and 84 and over as brachencephalic. All the specimens in this series are thus dolichencephalic, though not to the extreme degree shown by the brains described by Slome.

Castaldi found that of fourteen brains of Basuto, nine were dolichencephalic, and five mesencephalic, the mean value being 77·06. The Bush brain thus appears to be more consistently dolichencephalic than the Bantu. This is the reverse of what has been observed for the skull, the Bantu being characteristically dolichocephalic, while the Bush type is mesaticephalic. This discrepancy may be attributed to the fact that, owing to the feeble supraorbital development and small frontal sinuses which give to the Bush skull its smooth vertical forehead, the encephalic length in this type approximates more closely to the cranial length than in the case of the Bantu, with his prominent glabella and sloping forehead excavated by large frontal sinuses.

TABLE 2—ENCEPHALOMETRIC INDICES OF BUSHMAN ENDOCRANIAL CASTS.

No.	Side	General Height Index	Occipital Index	Temporal Depth Index	Temporal Length Index	Frontal Height Index	Frontal Length Index	Temporal Projection Index	Occipital Length Index	Rostral Depth Index
143.	L.	0·494	1·147	0·132	0·730	0·454	0·345	0·103	0·431	0·074
	R.	0·456	1·013	0·170	0·725	0·427	0·374	0·105	0·456	0·111
144.	L.	0·488	1·096	0·134	0·714	0·439	0·366	0·079	0·445	0·116
	R.	0·479	1·114	0·172	0·718	0·436	3·350	0·074	0·429	0·110
151.	L.	0·468	1·174	0·145	0·746	0·434	0·329	0·075	0·400	0·098
	R.	0·471	1·095	0·134	0·733	0·442	0·337	0·064	0·430	0·087
161.	L.	0·503	1·049	0·123	0·754	0·450	0·316	0·076	0·480	0·082
	R.	0·503	1·075	0·140	0·743	0·456	0·333	0·076	0·468	0·094
163.	L.	0·489	1·288	0·138	0·730	0·443	0·333	0·063	0·379	0·115
	R.	0·489	1·076	0·149	0·747	0·443	0·299	0·051	0·454	0·098
165.	L.	0·506	1·174	0·169	0·744	0·463	0·319	0·063	0·431	0·100
	R.	0·503	1·093	0·172	0·730	0·460	0·331	0·061	0·460	0·080
166.	L.	0·506	1·065	0·140	0·741	0·463	0·333	0·074	0·475	0·117
	R.	0·513	1·172	0·150	0·750	0·469	0·313	0·069	0·438	0·106
167.	L.	0·512	1·000	0·142	0·716	0·488	0·370	0·086	0·512	0·068
	R.	0·503	1·079	0·160	0·736	0·485	0·356	0·092	0·466	0·061
174.	L.	0·485	1·215	0·153	0·730	0·448	0·356	0·086	0·399	0·117
	R.	0·488	1·143	0·146	0·732	0·439	0·348	0·079	0·427	0·104
175.	L.	0·500	1·375	0·136	0·733	0·449	0·335	0·068	0·364	0·080
	R.	0·486	1·246	0·141	0·740	0·435	0·328	0·073	0·390	0·096
A26.	L.	0·480	1·133	0·147	0·701	0·441	0·362	0·073	0·424	0·102
	R.	0·520	1·257	0·106	0·704	0·475	0·358	0·073	0·413	0·067
	Average	0·493	1·140	0·146	0·732	0·452	0·336	0·076	0·435	0·095

It will be noted that in Table 1, both the greatest parietal breadth and the greatest temporal breadth are given. In primitive human brains, such as that of Rhodesian man, the greatest breadth is the bi-temporal, which considerably exceeds the bi-parietal. With greater cerebral expansion the parietal breadth comes to equal or exceed the temporal. The table shows that in the Bush endocranial cast, these two diameters are closely similar. It is curious that in four of the seven males the bi-parietal diamenter exceeds the bi-temporal, whereas in all the four females the bi-temporal equals or exceeds the bi-parietal. The numbers are too small, however, for any weight to be laid upon this.

Frontal Breadth Indices. (Table 1.) The fronto-parietal and fronto-temporal indices given in Table 1 show that the maximum frontal diameter in the Bush endocranial cast ranges between 70 and 80 per cent of the greatest breadth. It is to be noted that both indices are slightly higher, i.e the frontal region is relatively a little broader in the male than in the female. I have been unable to find comparative figures for these indices in the literature In the Rhodesian cast, however, the frontal width is 74·64 per cent. of the greatest (bi-temporal) diameter, very much the same as the Bush average, whereas in a European cast, it is 87·77 per cent., and in that of Dean Swift, 80 41 per cent. of the greatest diameter.

Both Kappers and Slome have noted " narrow width of the frontal lobes, or rather pronounced parietal width " among the distinguishing features of the Bush brain. This character has now been shown to be a consistent one in the present series. I am of the opinion, moreover, that this state of affairs results from definite narrowness of the frontal lobes, and not from exaggerated expansion of the parietal region, of which the measurements of this series afford no evidence.

General Height Index. (Table 2.) This index ranges from 0·456 to 0 520, with a mean value of 0·493. The mean value is slightly less than found by Slome on actual brains; both figures, however, approximate to Kappers' average figure for dolichocephalic Dutch brains (0·491). This result, which would not be anticipated from our knowledge of the cranial morphology of the Bushman, is similar to that obtained by Woollard (1929) for the Australian aboriginal brain. The value of this index, in fact, seems to be of the same order in all dolichocephalic types of *Homo sapiens*.

Castaldi obtained for the Basuto a mean index of 0·479. It is surprising to find in the high-skulled negro a lower index than in the chamaecephalic Bush. Dr. Galloway tells me, however, that the brains used by Castaldi, a series sent from the University of the Witwatersrand to the University of Florence, were not hardened *in situ* and may have sustained post-mortem flattening. Castaldi's figures show an extraordinary range, from 0·320

TABLE 3—COMPARATIVE TABLE OF ENCEPHALOMETRIC INDICES.

Race.	Author	General Height Index	Occipital Index	Temporal Depth Index	Temporal Length Index	Frontal Height Index	Frontal Length Index	Rostral Depth Index
Bushman (cast)	—	0·493	1·140	0·146	0·732	0·452	0·336	0·095
Bushman (brain)	Slome (1932)	0·512	1·202	0·143	0·747	0·461	0·329	—
Australian Aboriginal	Woollard (1929)	0·502	1·008	0·127	—	—	—	—
Dutch (dolichocephalic)	Kappers (1929)	0·491	1·190	0·145	0·748	0·443	0·346	—
Basuto	Castaldi (1936)	0·479	1·160	0·126	0·742	0·459	0·376	0·100

to 0·571. He found also that the mean index of the mesencephalic specimens (0·492) is higher than that of the dolichencephalic group (0·471). This result suggests the same trend of variation in this index as do the figures of Kappers, which show a considerably higher value in brachymorphic than in dolichomorphic types.

Occipital Indices. (Table 3.) The occipital index of Kappers ranges from 1·000 to 1·375, its mean value being 1·140. This is somewhat less than the value (1·202) obtained by Slome for the actual brain, and also than the figures for the dolichocephalic Dutch (1·190) and for the Basuto (1·160, a figure which should probably be higher if, as has been suggested above, these brains had been distorted). It is, however, greater than the mean value of Woollard for the Australian brain.

From this index it follows that the descending slope of the occipital region is, on the average, appreciably more gentle in the Bushman than it is in the dolichocephalic Dutch type. Since the height indices of these two types are identical, this must mean that the highest point is further forward in the Bush brain than in the Dutch. Woollard has observed this to be the case in his Australian series. To investigate this point further, I have in this series expressed the occipital length measurement as an index of the lateral horizontal line. The results show a wide range of variation, from 0·379 to 0·512, the mean value being 0·435. From Kappers' figures, it appears that the mean value of this index is of the order of 0·413 in Dutch dolichocephals; Castaldi's figures for the Basuto indicate a mean value of the order of 0·413, and those of Woollard for the Australian one of 0·489. Thus the highest point is placed further forward in the Bushman than in any other of these types with the exception of the Australian. So far as the Bushman and Basuto types are concerned this result is in accordance with our knowledge of the morphology of the skull. In the former the highest point is in the region of bregma, whereas in the latter it is vertically over or even behind the external auditory meatus (Galloway, 1937).

The range of variation of this index is doubtless to be correlated with the variation which may occur in the occipital contour of this race, from the prominent, wedge-shaped, "foetal" occiput of the Boskopoid type to the more rounded "infantile" occiput of the purer Bushman.

Temporal Indices. (Table 2.) The temporal depth index ranges from 0·106 to 0·127, giving a mean value of 0·146. This agrees closely with that obtained by Slome for the actual brain (0·143), and with Kappers' average for Dutch dolichocephals (0·145); on the other hand, lower values are obtained by Woollard for the Australian (0·127), and by Castaldi for the Basuto (0·126). In the latter group it is possible, however, that post-mortem flattening of the temporal lobe had occurred. It is evident that

downward development of the temporal lobe in the Bushman is of the same order as in the Dutch dolichocephal; further, it is to be noted that the Rhodesian endocranial cast gives an index very close to the means of those groups.

On the other hand, the temporal length index, which ranges from 0·701 to 0·754, has a mean value of 0·732; this is appreciably less than any of the figures given by Kappers. Slome, however, found for the actual brain a value of 0·747, almost identical with that of Kappers for the Dutch dolichocephals (0·748). For the Basuto, Castaldi obtained an index of 0·742, which is unlikely to have been influenced by distortion. The index was not determined by Woollard in the Australian.

From this series, it appears, that the temporal lobe in the Bush brain has a less degree of anterior projection than that of other races examined. An attempt has been made to confirm this by measuring the amount of projection of the temporal pole in front of Kappers' chiasma perpendicular, and expressing this as an index of the lateral horizontal line. The values obtained range from 0·051 to 0·105, with a mean of 0·076. In other types a measure of the value of this index is afforded by the amount by which the sum of the temporal length index and the frontal length index of Kappers exceeds 1·000. This amount is 0·076 in Slome's Bush series as against 0·094 in the dolichocephalic Dutch and 0·118 in the Basuto. Thus, again, a marked abbreviation of the temporal pole in the Bushman seems to be indicated. These results, may, however, be affected by variation in the frontal length, which have still to be considered. It is highly significant in this connection that Kappers finds the average of the temporal index in the last two months before birth to be 0·700. The shortness of the temporal lobe in the Bushman seems therefore to be an infantile character.

Frontal Indices. (Table 2.) The front length index ranges from 0·299 to 0·374, its mean being 0·336. This is slightly greater than the mean obtained by Slome from the actual brain (0·329). Both these values are, however, less than those stated by Kappers for Dutch dolichocephals (0·346), and by Castaldi for Basuto (0·376). This series thus confirms the finding of Slome, that the frontal region is relatively short in the Bushman. As Slome points out, it is highly significant the results most comparable to those found in the Bushman are those obtained by Kappers for foetuses and newly-born infants (0·326), and for Rhodesian man (0·332). Shortness of the frontal region thus appears to be an infantile and also a primitive character.

Comparison of the frontal length with the temporal projection in the Bush series shows that while in general terms, increase in the one is accompanied by increase in the other there is no close correlation between them. Kappers' results also indicate that there is no definite correlation between frontal length and temporal length. Thus it may be concluded that the

variations already noted in the projection of the temporal pole in front of the chiasma perpendicular are not artefacts due to a change of position of that perpendicular, but represent a definite variation in the length of the temporal lobe.

The frontal height index ranges from 0·427 to 0·488, with a mean of 0·452. This is slightly less than that found by Slome for the actual brain (0·461), but exceeds that for Dutch dolichocephals (0·443); it is exceeded by that of the Basuto. Woollard's index is determined by a method different from that used for those other series and is not comparable with them. So far as this index goes, it shows no evidence of marked depression of the frontal lobe in the Bushman. This rather unexpected result is in accordance with that obtained from the general height index. These discrepancies tempt one to suggest that the method of estimating encephalic heights devised by Kappers is not in practice an accurate measure of the endocranial height.

The index of rostral depth ranges from 0·061 to 0·117 with a mean of 0·095, which is very similar to that of 0·100 for the Basuto. This index is not given by other workers.

From this metrical analysis it has emerged that the Bushman is characterised by a brain of small volume, consistently elongated (dolichencephalic), the bi-temporal and bi-parietal diameters approximately coinciding, the frontal region narrow and also short, the anterior projection of the temporal pole abbreviated, the highest point of the brain placed relatively far forward so that the occipital slope is long and gentle. The shortness of the frontal and temporal lobes seem to be infantile features.

These facts, though of great value, give a very incomplete picture of the peculiar morphology of the Bushman brain.To fill in the outlines of this picture the non-metrical features of the brain must be considered.

III—Morphological Features.

Shellshear and Elliot Smith (1934) have stated that: "In dealing first with the description of the sulcal pattern as a general introduction to the cerebral morphology of *Sinanthropus* we are alive to the lesser importance of this in comparison with that revealed in the study of form and proportions. There are areas of localised elevation and areas of depression which are significant in interpreting the evolutionary changes which are responsible for determining the higher types." In this study, I have preferred to concentrate upon this latter aspect of the subject, reserving for a subsequent investigation the examination of the details of sulcal pattern revealed in the casts.

Before embarking on this description it may be well to review our knowledge of the morphological features of the Bushman brain.

Slome (1932) concluded that the distinctive features of the gross morphology of the Bushman brain were narrow width of frontal lobe, frontal and occipital flatness, and exposure of the insula. The rostrum orbitale he did not find to be excessively developed, while the sulcus lunatus was well developed in only two out of five hemispheres, in both cases on the left side.

Shellshear in his discussion of Marshall's specimen (1933) stresses as especially primitive the following features: "The occipital region . . . presents on both sides a wide lateral expansion of the area striata with fully developed sulci lunati and intrastriate sulci of primitive form. . . . The main expansion (of the parietal region) appears to have taken place in the region of the supramarginal lobule. The temporal lobe is narrow and lacks fullness. Anteriorly the temporal pole is narrow and slender, and fails to extend forward to cover the posterior part of the orbital surface of the frontal lobe. Associated with the general under-development of the temporal lobe is the exposed condition of the Island of Reil on both sides. The frontal lobe shows primitive features of both form and sulcal pattern. Marshall emphasised the peculiar narrowing of the frontal lobes, with prominent antero-external angles. In this respect the form of the brain of the Bushwoman is very similar to that of *Pithecanthropus*." Elsewhere Shellshear expresses the opinion that "the Bushwoman's brain shows a degree of primitiveness and lowliness which places it only slightly, if at all, above that of *Homo Rhodesiensis*."

To this description Shellshear adds the important comment: "Whilst the question of racial difference is one of great interest, it is necessary to emphasise that this is the description of the brain of an individual Bushwoman, and therefore of morphological rather than of racial importance. It may be that the very primitive features to be described point to the lowly condition of the race to which she belongs; but in the present state of our knowledge the evidence of this form one specimen must be inconclusive."

Shellshear and Elliot Smith (1934) have given a detailed comparison of the endocranial cast of *Sinanthropus* with that of a Bushman, which they remark "shows a somewhat more developed brain than that of Marshall's Bushwoman." This account may be excerpted at some length, since it represents our most important source of information regarding the gross morphology of the Bush endocranial cast.

> "Compared with that of *Sinanthropus* the Bushman cast is seen to be uniformly enlarged. There has been significant expansion of new areas, but there is also apparent a general increase of the areas already present in *Sinanthropus*. In the occipital region the lambdoidal suture is placed relatively further back. The elevation of the occipital opercular region (area striata) although apparent in the cast,

is hardly visible from the dorsal aspect. . . . The walls of the inferior parietal region have grown vertically upwards . . . the parietal eminences are relatively further forward than in *Sinanthropus;* and posterior to them there is a general and uniform enlargement of the cortex, which would correspond with the new development of those cortical areas which have been shown by the researches of Flechsig, Brodmann and others (in Elliot Smith's 'Evolution of Man,' page 163) to be the last formed in the higher races.

"On the cast itself the parietal eminences occupy a position corresponding to the posterior end of the fissure of Sylvius. Above the eminences the surface of the brain as it passes to the vertex is uniformly filled out, and there are no depressions which could be interpreted as sulci. Posteriorly, the pre-occipital region is uniformly filled out, and there is no longer a parieto-occipital depression which forms such a distinctive feature in the cast of *Sinanthropus* and Rhodesian man. Below the parietal eminence the temporal eminence is still present at the posterior end of the second temporal convolution, but very significant changes have taken place in the temporal area. It has filled out below, and the angle between it and the cerebellum has become much more acute. Anteriorly the temporal pole is bolder, its edges are filled out, and its surface is only very slightly depressed below the level of the frontal and parietal contour. The tip of the temporal pole still lies slightly posterior to the tip of the frontal cap. Relative to the coronal suture there is a fuller development of the region of the frontal cap. Although the length of the temporal area has increased it still fails to reach the tip of the frontal cap; this suggests that the cortex of the inferior frontal region has been pushed forward in the general expansion.

"In the frontal region there is a keel which is large, but looks less simian than does that of *Sinanthropus.* This is due to the general thickening of the orbital margin. The cast of the Bushman is remarkable in that as compared with the casts of higher races, the frontal region is markedly depressed. It is depressed almost to the extent revealed in Rhodesian Man. This depression is accentuated by the prominence of the coronal eminence and by the thickening of the inferior frontal region extending from the precentral region almost to the frontal pole."

The cast No. 174 of the series, which approximates very closely in all its metrical features to the average values for the series has been selected as the type specimen for illustration and description. The features in which other members of the series differ from this will be noted as the description proceeds. For comparison, not having an endocranial cast of *Sinanthropus* at my disposal, I have used that of Rhodesian Man as a type of early human brain This cast has been described in detail by

Elliot Smith (1928), and he was able to write at that time: "Hence there is revealed in the Rhodesian cast a much more striking demonstration of the development of the cerebral hemisphere that is going on within the human family than in any other cast." Comparison has been made also with the European endocranial casts in our collection. For certain features, comparisons have been made with the described endocranial casts of the pre-Bush Boskop race. These comprise the casts from the original Boskop skull described by Elliot Smith (1918), that of the Zitzikama skull described by Dart (1923), and the frontal portion of that of the skull M.R. 1 from Matjes River, studied by Meiring (1936).

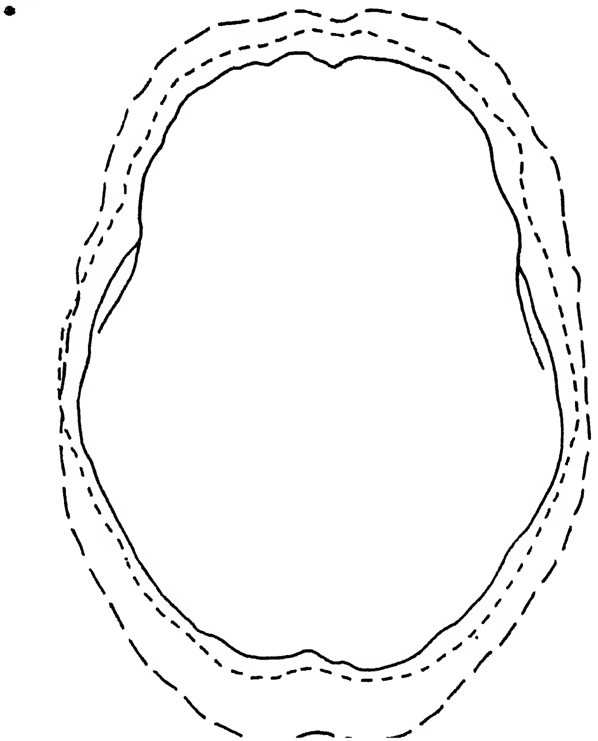

Fig. I—Contour in *norma verticalis* of typical Bushman endocranial cast (continuous line) superimposed on those of Rhodesian Man (dotted line) and a European (interrupted line); 1 × ½.

Frontal Region. Metrical analysis has shown that the frontal region of the Bush brain is both shorter and narrower than that of the European. The contrast between the narrow frontal region and the laterally projecting eminences gives to the cast a most distinctive contour in *norma verticalis* (Fig. I). This contrast is accentuated by the slight constriction of the frontal

lobes in the coronal region from which the parietal region flares out abruptly to the parietal eminence, giving the brain in this view almost an hour-glass shape. Owing to the frontal narrowing, moreover, the lateral contour behind the Sylvian notch is formed by the temporal lobe, a part of the supero-lateral surface of which is visible from above. More posteriorly, the temporal contour is overlapped and masked by the parietal eminence, whereas in Rhodesian Man the temporal contour is visible through its whole length. The lesser degree of parietal expansion in Rhodesian Man gives the cast of this type a less hour-glass shaped appearance than that of the Bushman, although the outlines of the two casts are almost identical. In the European casts examined, the contour is evenly ellipsoidal, there is no marked Sylvian depression, and the broader frontal lobe completely conceals the temporal contour.

Anterior to the Sylvian depression the frontal lobes of the Bush cast have an almost quadrilateral outline in *norma verticalis* due to the prominence of the antero-external angles. As Figure I shows this contour is almost identical with that of Rhodesian Man; Shellshear and Elliot Smith have remarked on the fact that *Pithecanthropus* also shows this feature, whereas in *Sinanthropus* the antero-external angles are less prominent, giving to the frontal lobes a more pointed, simian contour. In the European casts, on the other hand, these angles are not apparent, the frontal lobe in this view being filled out to a rounded contour.

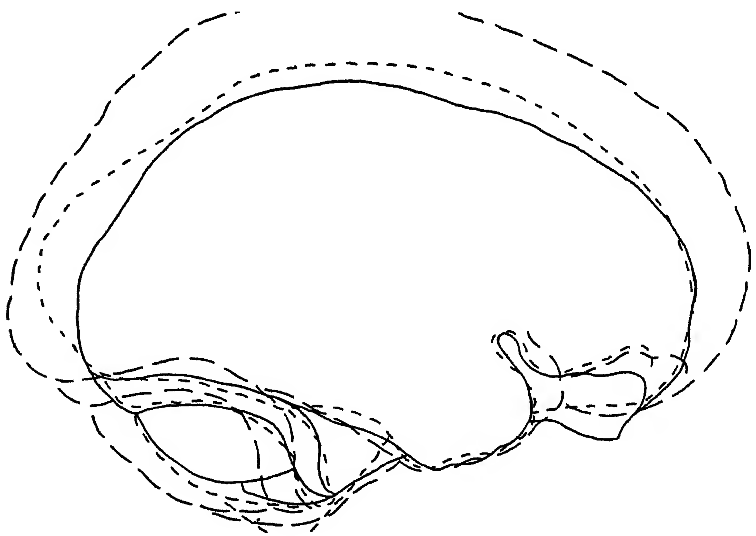

Fig. II—Contour in *norma lateralis* of typical Bushman cast (continuous line) superimposed on those of Rhodesian Man (dotted line) and European (interrupted line); 1 × ½.

The lateral view (Fig. II) shows the downward projection of the orbital rostrum in the Bushman cast. This rostrum is limited almost entirely to the region below the lateral horizontal line of Kappers, the lateral orbital margin approximately coinciding with this line, an arrangement common to the majority of the specimens in this series. Both in Rhodesian Man and in the European this margin curves upwards so that a part of the rostrum lies above the lateral horizontal line. In Rhodesian Man this margin has an even upward convexity, whereas in the European the convexity is broken by the downward projection of the fronto-orbital convolution. This downward projection is also recognisable in the Bushman; it is a part of a general expansion of the inferior frontal region in the *Homo sapiens* types as compared with Rhodesian Man. In two of the Bush specimens, however (Nos. 151 and 167), the margin has the same even convexity as in Rhodesian man, extending well above the lateral horizontal line.

The downward deflection of the orbital margin and orbital rostrum in the Bush endocranial casts corresponds to the similar deflection of the ethmoid part of the basi-cranial axis to which Keith (1929) has directed attention in the Bushman skull. Keith has rightly emphasised that this is a persistent juvenile feature. The relatively large rostrum is reflected also in the skull by the deep and relatively narrow cribriform fossa.

The greater expansion of the inferior frontal region in the Bushman as compared with Rhodesian Man is also manifested in Figure II by the greater prominence of the anterior contour just above the level of the orbital margin. There is also in the Bushman a second prominence above this, representing the anterior extremities of the middle and superior frontal gyri, which is much less accentuated in Rhodesian Man. In the European, however, this upper prominence is developed to a much greater degree than in the Bushman, completely overshadowing the prominence of the inferior frontal region.

The difference in the contour of the frontal pole in this norma between the Bushman and European casts is expressed to some extent in the profile of the frontal region of the skull. The vertical contour of the narrow low forehead of the Bushman is derived from the fact that the well developed lower and moderate upper frontal prominences are only slightly obscured by the feeble supraorbital ridges and small frontal sinuses. In the European, in spite of the presence of much larger sinuses and ridges, the broad forehead has a vertical or nearly vertical contour, as well as a greater height, on account of the great development of the upper frontal prominence.

While it has been found that metrically the frontal region of the Bush endocranial cast is not lower than that of the European, this by no means accords with the visual impression given by the Bush frontal lobes, which is one of marked flattening. This

impression is created largely by the presence in the superior pre-frontal region of a triangular unexpanded area which is precisely similar to that described by Elliot Smith in the Rhodesian endocranial cast, except that its inferior and anterior extent is limited by the greater expansion of the inferior frontal region and the anterior extremities of the superior and middle frontal convolutions.

The contrast in this respect between the frontal lobes of Rhodesian Man, the Bushman and the European is clearly revealed by Figure IIIA, where comparison is made between coronal sections passing through the *pars intermedia (triangularis)* of the inferior frontal gyrus in the three types. In the Rhodesian cast the inferior frontal region forms a knuckle-like projection at the junction of the lateral and inferior surfaces of the frontal lobe. It has already been remarked that in the Bushman this territory is considerably more expanded. This is clearly evident from its greater convolutional complexity as compared to the Rhodesian type (Fig. IV). Because of this, the inferior frontal region in the Bushman forms a broad, evenly rounded boss, whose infero-lateral projection appears correspondingly less abrupt than that of Rhodesian Man.

In the European cast, the inferior frontal region is not, relative to the size of the whole brain, more expanded than in the Bushman; this is shown by a comparison of the convolutional development in the two types (Fig. IV). However, as Figure IIIA shows, it has become rotated outwards and downwards by the expansion of the more dorsal portions of the cortex, so that the greatest diameter of the frontal lobe is found, not as in the Bushman, near the lower border of this region, but in the neighbourhood of its upper border.

The unexpanded superior and middle frontal territories in the Rhodesian cast form a slightly convex surface facing upwards and laterally. In the Bushman, their contour is similar, but the middle frontal region appears relatively better developed, giving a bolder convexity. The contour in the European cast is strikingly different, the great expansion of these territories having produced a bold, evenly convex, laterally projecting contour.

The median dorsal ridge of the Rhodesian cast is not due to the brain, but to the sagittal blood sinuses and cerebro-spinal fluid stream; the similar ridge in the European cast is produced in the same manner. It is noteworthy that no such ridge is present in the Bush cast, the position of the cerebro-spinal stream being marked only by a slightly flattened area. This suggests also that the sinus may be a flatter, less triangular structure in the Bushman than in the European.

Meiring (1936) has demonstrated that in the pre-Bush skull M.R. 1 from Matjes River Cave, the inferior frontal region is less expanded than that of the Bushman. I have been able to verify this by examination of a cast of the frontal lobe of this

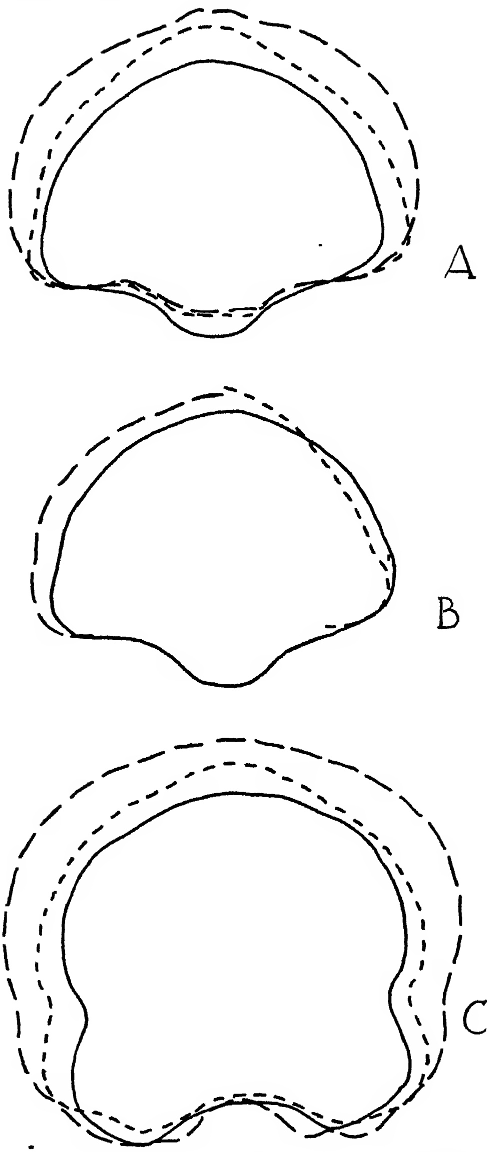

Fig. III—Coronal contours of the frontal lobe: A, passing through the *pars intermedia* of the inferior frontal gyrus in Bushman (continuous line), Rhodesian Man (dotted line) and European (interrupted line); B, at the same level in Bushman (continuous line), original Boskop cast (interrupted line) and Matjes River cast (dotted line); C, passing through the *pars posterior* of the inferior frontal gyrus in Bushman (continuous line), Rhodesian Man (dotted line) and European (interrupted line); 1 × 1.

specimen, kindly loaned to this Department by Professor T. F. Dreyer. In Figure IIIB, a contour tracing of this specimen is compared with that of the Bushman. It will be seen that in the narrowness of the inferior frontal protrusion and the slight convexity of the superior and middle frontal areas, the cast of M.R. 1 shows less development than that of the Bushman and approaches that of Rhodesian Man. The height and narrowness of this cast is a reflection of the trigonocephalic form of this skull (Keith, 1933).

The formation of this region in the endocranial cast of the original Boskop specimen at first glance appears to differ markedly from that shown by M.R. 1, the frontal region being compressed from above downwards instead of from side to side. The Boskop cast, however, agrees with that of M.R. 1 in having an inferior frontal region less expanded than that of the Bushman. The middle and inferior frontal territories are also unexpanded. The triangular area of depression formed by these territories is more accentuated in the Boskop cast than in that of the Bushman. Because of it, the expansion of the anterior extremity of the superior and middle frontal gyri, which is present in Boskop man as in the Bushman, is particularly sharply defined, giving a peculiar appearance to the frontal poles. The endocranial cast of the Zitzikama skull, so far as it is preserved, reproduces the features of the original Boskop cast.

The differences in the development of the upper and lower parts of the frontal lobe. between the Rhodesian, Bushman and European casts, are also seen in a coronal section traversing the *pars posterior (basilaris)* of the inferior frontal gyrus (Fig. IIIc). In Rhodesian Man and the Bushman, this part of the inferior frontal gyrus is less salient than the more anterior portion, contributing to the coronal constriction of the brain in *norma verticalis* (Fig. 1). On the other hand, in the European cast, this region has been carried outwards and downwards, like the more anterior portions of this gyrus, by the expansion of the middle and superior frontal territories. It is in this outward and downward movement of the *pars posterior* which causes it to overlap the insular region, of which it constitutes the fronto-parietal operculum.

In this profile the lack of expansion of the middle and superior frontal regions in the Rhodesian cast is very apparent. In the Bushman, however, it is evident, more than was the case in the previous figure, that there has been some expansion of the middle frontal gyrus, though to a much less degree than in the European. It is to be remarked that the sagittal vascular ridge is conspicuous only in the Rhodesian cast.

The coronal ridge ascribed to the ascending cerebro-spinal stream along the line of the coronal suture (Keith, 1931) is not a prominent feature of the Bushman casts, and spreads out rapidly into a broad flat fan. This flat and ill-defined character has already been noted in the coronal stream. In this respect,

the Bushman resembles the European, whereas in Rhodesian Man and in Boskop Man the coronal ridge is narrow, sharply defined, and very prominent. Elliot Smith (1918) has remarked on a prominent coronal ridge as a feature of the more primitive types of human skulls.

The contour of the frontal lobes of the Bush brain is reflected in the features of the frontal region of the brain case, with its low vertical sides and flattened roof. Further, the projecting boss constituted by the inferior frontal territory excavates for itself a recess in the thin cranial wall which is reflected externally as a rounded elevation, to which I called attention in 1929 as a consistent feature of the Bush skull, under the name of *inferior frontal eminence.*

The formation of this eminence in the Bush skull results from the combination of the prominent inferior frontal region with a thin-walled brain case. An inferior frontal eminence is therefore not present in such skulls as those of Rhodesian Man and Boskop Man, in which the inferior frontal region is less salient, while the overlying cranial wall is thicker. It is also absent from the skull of the European, in whom the prominence of the inferior frontal region is lost in the general expansion of the frontal lobe.

Temporal Region. In all the casts of this series, the region of the stem of the Sylvian fissure forms a broad and deep depression equal to that of the Rhodesian cast (Figs. II, IV, V). The presence of this feature implies, as Elliot Smith has pointed out in the case of Rhodesian Man, that the insula (of Reil) was partially exposed, instead of being wholly concealed by the opposed lips of the fissure as is the case in the European. Dart (1923) pointed out that in the Zitzikama cast, the Sylvian fissure is also widely open, showing that the insula was exposed in this type also. The exposure of the insula in the Bushman results from the poor development of two of its opercula, the fronto-parietal and temporal. The former of these has already been discussed; the latter still remains to be considered.

The shortness of the temporal pole in the Bush endocranial cast, revealed by measurement, is demonstrated visually by the fact that the tip of the temporal lobe consistently falls short of the greatest downward projection of the inferior frontal boss. This is shown by the superimposed contours in Figure II, and and also in Figure IV. As a result of this the temporal pole does not encroach upon the orbital surface of the frontal lobes to nearly the same extent as in the European. The figures show that this difference is due to the lack of development of the temporal polar area in the Bushman. In the Bushman, the temporal pole forms a tapering extremity well below the inferior surface of the frontal lobe, whereas in the European it is carried forward and upward in an even convexity to establish contact with the frontal lobe, and as the temporal operculum to overlap completely the Island of Reil.

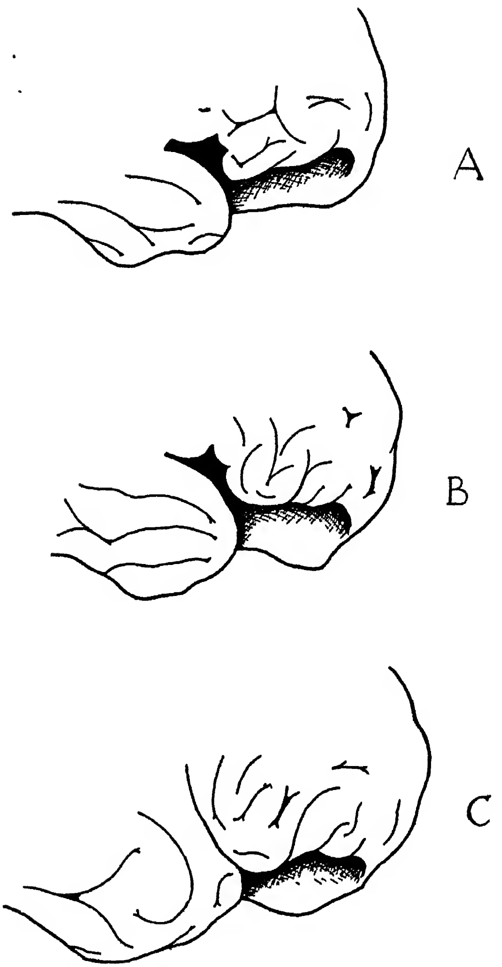

Fig. IV—Diagram of the region round the stem of the Sylvian fissure in A, Rhodesian Man; B, Bushman; C, European; the drawing of Rhodesian Man is a mirror image of the left side of the cast; 1 × ½.

Compared with the slender, almost atrophic-looking temporal lobe of Rhodesian Man, that of the Bushman has undergone considerable expansion. This has taken place principally in a downward direction. Its effect has been, anteriorly, to widen out the temporal pole so that its lower margin has a form closely similar to that of the European. More posteriorly, there has been a marked widening of the inferior frontal gyrus. This in turn has brought about a narrowing of the temporo-cerebellar

recess from the wide fossa seen in Rhodesian Man and in *Sinanthropus*, to a narrow deep inlet much more similar to that of the European.

In spite of this inferior expansion, the posterior portion of the Bush temporal lobe reveals a very significant resemblance to that of Rhodesian Man in the presence of a well-defined temporal eminence. This is well brought out in Figure VA. The contour of the Rhodesian cast here shown corresponds to that illustrated and discussed by Elliot Smith. It will be seen that the temporal boss in the Bush cast is as well defined by the broad Sylvian depression above it as that of the Rhodesian cast; its convexity is continued downwards by the expanded inferior temporal area. In the European cast the prominence of the temporal boss is almost entirely lost in the expansion of the surrounding areas.

This eminence is well marked in all save one (No. 143) of the specimens in this series. As the measurements have indicated, its prominence tends to be greater in the female specimens than in the males.

The form of the temporal lobe in the Bush brain is reflected like that of the frontal lobe, in the external form of the skull. Dart (1924) first remarked, under the name of *mons temporo-sphenoidale*, a rounded prominence along the temporo-sphenoidal suture, encroaching upon the temporal fossa, which has been considered to distinguish the Bush skull from those of other African types of *Homo sapiens*. It has been noted by Galloway (this JOURNAL, p. 113) that the *mons temporo-sphenoidale* is present also in Rhodesian Man and *Sinanthropus*.

This prominence is due to the interplay of several features of the brain. The first of these is the narrowness of the frontal region relative to the parietal region, with the concomitant coronal constriction, as a result of which the temporal lobe projects laterally beyond the fronto-parietal region (Fig. I) Even the inturned anterior extremity of the temporal lobe is, in the Bushman and in Rhodesian man, barely overshadowed by the frontal lobe, which in the European projects far beyond it (Fig. IIIB). Another important contributing factor is the wide interval between the truncated temporal pole and the under surface of the frontal lobe, and the breadth and depth of the Sylvian depression intervening between them. The temporal pole, instead of its contour flowing without interruption into that of the frontal lobe, as is the case in the European, is thus isolated. It is the moulding of the brain case over this isolated extremity and laterally projecting temporal lobe which produces the *mons temporo-sphenoidale*. In the skull of the Bush physical type, the Sylvian depression is represented on the exterior by a groove intervening between the inferior frontal eminence, in front and above, and the *mons temporo-sphenoidale* behind and below.

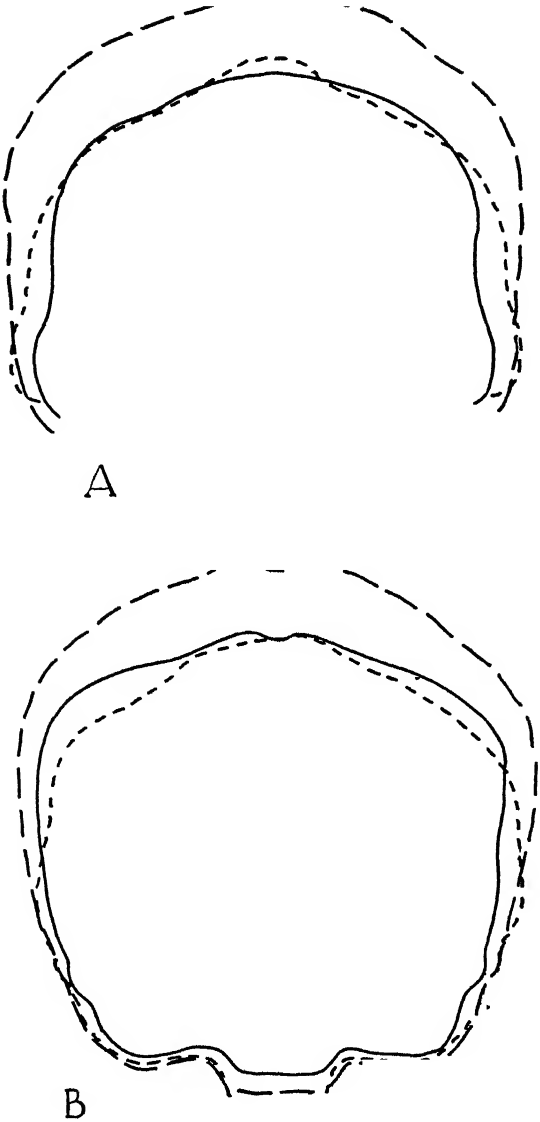

Fig. V—A, Coronal contours drawn through the most prominent part of the temporal lobe in Bushman (continuous line), Rhodesian Man (dotted line) and European (interrupted lines; 1 × ½. B, Coronal contours drawn through the most prominent part of the parietal eminence in Bushman (continuous line), Rhodesian Man (dotted line) and European (interrupted line); 1 × ½.

The prominence of the *mons temporo-sphenoidale* in the Bushman skull may be continued backwards as a convex protrusion along the line of the parieto-temporal suture. This protrusion can be due only to the sailent temporal eminence. Such a protrusion has been noted particularly in juvenile skulls; it is possible therefore that an exaggerated prominence of the temporal boss in relation to the parietal boss, noted in this series as most common in females, is to be considered an infantile character. A consequence of the prominence of this boss is that the maximum breadth of the skull is found on the parieto-temporal suture, or even on the upper portion of the temporal squama, instead of on the parietal bone. This is a feature of the more primitive types of humanity such as Rhodesian man.

Parietal Region. Figure VA also shows the contour of the anterior part of the parietal region. In the Rhodesian cast the Sylvian depression is bounded above by a low convex prominence which is the anterior extension of the inferior parietal area of expansion, while above this again is the Rolandic area of depression. The contour in the Bushman is closely similar, except that the inferior parietal expansion is more pronounced and extensive, while the Rolandic depressed area is correspondingly limited in extent. In the European the contour has become almost one even convexity, and the Sylvian depression has practically disappeared, though as Elliot Smith has remarked, a slight flattening is still perceptible in the Rolandic area.

The salient parietal eminence of the Bushman cast occupies the same position as the less prominent one of Rhodesian Man, in the supramarginal at the posterior end of the Sylvian fissure. In Figure VB, comparison is made between coronal profiles of the Rhodesian, Bushman and European casts taken through this eminence. This profile in the Rhodesian cast traverses the posterior part of the temporal eminence, which still forms a prominent feature; in the Bushman it is also apparent, but of much smaller dimensions, while in the European cast no such projection upon the temporal lobe is discernible.

These contours show beyond doubt the homologous nature of the parietal eminences in the Rhodesian and Bushman casts. Compared with that of Rhodesian Man, however, the parietal eminence of the Bushman has expanded upwards and outwards. Its upward growth has separated it from the temporal eminence by a much greater distance than in Rhodesian Man, while growth in an outward direction has caused it to project laterally, overshadowing the posterior portion of the temporal lobe. This lateral projection produces the abrupt flaring outwards of the parietal lobe from the narrow frontal region and gives the sharp lateral angles to the parietal contour in *norma verticalis* (Fig. I). In the cast of the European, the parietal eminence is merged in the general expansion of the parietal region.

The parietal eminence of the Rhodesian cast is separated from the midline by a broad depression representing the unexpanded superior parietal area. In the majority of the Bush casts also, this region is clearly less expanded than the inferior part of the parietal lobe, being flattened or even, as in the specimen illustrated, slightly concave. Two specimens, however, show a slight even convexity, but this cannot be compared with the bold upward convexity of the European cast.

A similar variability is shown in this region by the endocranial casts of Boskop Man (Fig. VIA). In the original Boskop specimen the superior parietal region shows an even, though slight, convexity, but in the Zitzikama cast there is a marked depression between the midline and the parietal eminence. That eminence, however, is less salient than in the Bushman, and is in much closer contiguity to the well developed temporal eminence. The contour of this cast is thus generally intermediate between those of Rhodesian Man and the Bushman.

It is the well-developed parietal eminence of the Bush brain which determines the presence of the prominent "foetal" boss on the parietal bone, giving the Bush skull its characteristic pentagonoid cranial form. A similar effect is produced by the parietal eminence in the Boskop type. Further, in Rhodesian man and in *Sinanthropus*, the parietal bone shows a definite "foetal" boss corresponding to the parietal eminence of the endocranial cast, which, however, does not produce the conventional pentagonoid outline in *norma verticalis*, since it is wholly situated on the dorsal aspect of the skull. This clearly results from the lack of expansion of the parietal region as a whole. Because of this lack of expansion, the parietal bone is practically limited to the roof of the brain case, and does not enter into the formation of its lateral wall. With the expansion of the inferior parietal region, the lower part of the parietal bone comes to form a part of the vertical lateral wall of the brain case, and the parietal boss is situated at the junction of wall and roof, so determining the contour in *norma verticalis*. The flat unexpanded superior parietal region gives the Bush skull its flattened vault in contrast to the boldly convex vault of the European skull.

Parieto-occipital Region. Figure II shows the vast difference in the parieto-occipital contour between the Rhodesian and Bush casts. In the former, there is a strongly marked transverse parieto-occipital depression; in the latter, the occipital region descends in a convex curve interrupted only by a slight indentation at the level of the lambdoid suture, such as is present equally in the European. Thus, in spite of the relatively anterior position of the highest point, the parieto-occipital contour of the Bush cast does not differ markedly from that of the European. This implies a considerable expansion of this region in the Bushman as compared with Rhodesian man.

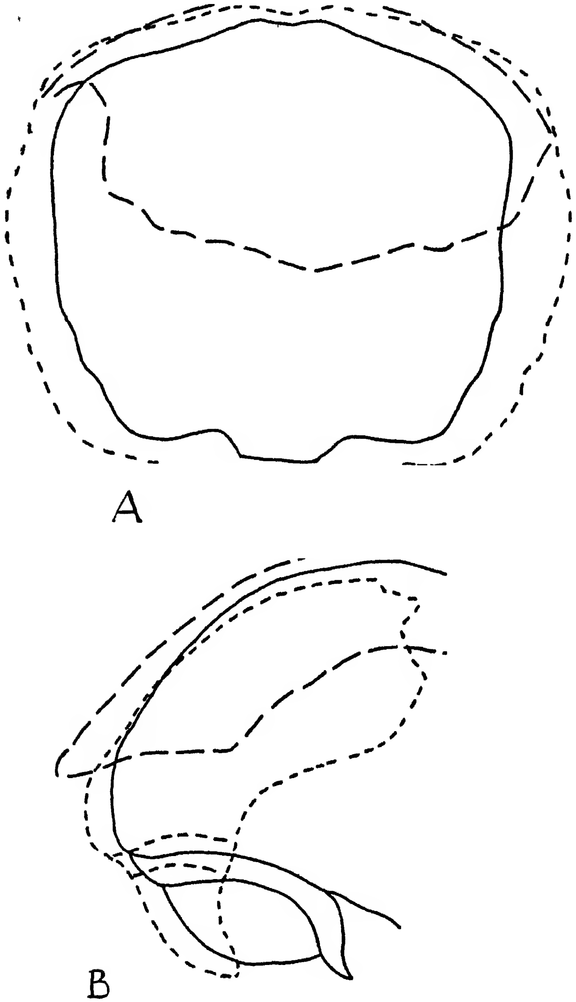

Fig. VI—A, Coronal contours drawn through the most prominent part of the parietal eminence in Bushman (continuous line), original Boskop cast (interrupted line) and Zitzikama cast (dotted line); 1 × ½. B, contour in *norma lateralis* of the parieto-occipital region in Bushman (continuous line), original Boskop cast (interrupted line) and Zitzikama cast (dotted line); 1× ½.

In the Boskop and Zitzikama casts (Fig. VIB), the parieto-occipital contour, though not depressed as in Rhodesian man, has a longer and more gentle slope than in the Bushman, the projection of the occipital pole behind the plane of the parietal eminences being relatively greater. The difference in the

tracings is not, however, so marked as inspection of the casts had suggested. This elongation and flattening of the parieto-occipital region is present also in one of the Bush casts (No. 161). It results in a wedge-shaped, "foetal" type of occiput, whereas the shorter, more convex contour typical of the Bushman cast produces a more rounded "infantile" occiput.

In the Rhodesian cast, the parietal and temporal eminences are defined posteriorly by a flattened area on the lateral aspect in the temporo-occipital region. This flattened area is an even more conspicuous feature in the Bushman cast, being accentuated by the development of the parietal eminence on its antero-superior border, and also by the filling out of the parieto-occipital region above it. In three of the Bush casts (Nos. 165, 166, and 174) it appears not merely as a flattened area, but as a marked depression. Such a depression is present also in the Zitzikama endocranial cast. In the European cast, this flattened or depressed area has disappeared, being replaced by a convex contour forming part of the general expansion in which the parietal and temporal eminences are merged.

This temporo-occipital flattened or depressed area is another feature which is reflected in the external form of the Bushman skull. The presence of a flattened, or more rarely concave, region of the cranial wall just above the asterion was pointed out as a consistent feature of the Bush skull by Berry (1934). It had previously been recognised that in the Boskop type of skull this area is generally concave; it may be concluded that a flattened contour of the supra-asterionic region is typical of the pure Bush skull, while the concave profile points to Boskop influence.

The form of the occipital pole is determined by the extent of the visual area of the brain, or *area striata*, which occupies the occipital pole, and is limited laterally by the lunate sulcus. In primitive types, this area is very extensive, the lunate sulcus being situated in the region of the lambdoid suture. Its extent combined with the lack of expansion of the parieto-occipital territory in front of the lunate sulcus cause this area to have the appearance of a cap applied over the occipital pole. This is the condition in *Sinanthropus*, Rhodesian Man and Boskop Man; Shellshear and Elliot Smith state that it is present also in the Australian aboriginal.

In all of the Bushman casts, the impression of the lunate sulcus is detectable. It lies well behind the lambdoid suture, so that the visual area is relatively much less extensive than in primitive types such as Rhodesian man. Because of this, and of the filling out of the parieto-occipital region, the visual area has not the appearance of a cap placed over the occipital pole, but rather of a flat disc forming its tip. The occipital pole in the Bushman thus tends to have a square profile. In the European, in whom the extent of the visual area is relatively

still further reduced, the occipital pole has a more rounded extremity.

The reduction of the relative extent of the visual area is accompanied by a tendency for the lunate sulcus to lose its primitive regularity, and to become broken up, so that in the European its vestiges are recognisable only with difficulty. The impressions on these Bush casts indicate, however, that although the visual area was not extensive, the lunate sulcus must, in all the specimens, have been fairly regular and easily recognisable.

Elliot Smith has laid stress upon the fact that while in other primates, the visual areas of the two hemispheres are symmetrical; in all types of man, with the exception of *Sinanthropus*, they are asymmetrical. The asymmetry has been ascribed to the preponderant use of one hand, the more extensive visual area being on the side opposite to this predominant hand.

It has been found that in five of the eleven casts in this series the left visual area is the more extensive, in four there is approximate symmetry, and in two, the right area is more extensive. On the other hand, it has been observed that in all of these subjects the bones of the right arm are more powerful (Bernstein, 1934): from this it has been inferred that all the individuals were characteristically right-handed. These discrepant results cannot invalidate the truth of Elliot Smith's generalisation, which is supported by far more extensive evidence. Rather, they suggest that in so far as the Bushman cast does not, in its asymmetry, reflect a preponderant right-handedness of this group, it is to be regarded as primitive.

IV—Discussion.

From the metrical and non-metrical analysis of this series of casts, it has been shown that they correspond in practically all of their distinguishing features. Comparison of the results of this analysis with the findings of other observers on the Bushman brain and endocranial cast show that many of these features equally characterise their material. These correspondences may be briefly reviewed.

The small size and narrowness of the brain were present to an exaggerated degree in Slome's material. This author noted also the narrowness, shortness and flattening of the frontal lobes. The angular contour of the frontal lobe in *norma verticalis* has been observed by Shellshear. Shellshear and Elliot Smith recorded the presence of the superior frontal area of depression and the expansion of the inferior frontal region. These authors also remarked on the size of the orbital rostrum, which Slome, however, found to be a variable feature.

Shellshear, and also Shellshear and Elliot Smith, have stressed the shortness of the temporal lobe, which, however, was not detected metrically by Slome. They have noted the tapering form of the temporal pole and its isolation from the frontal lobe.

Slome found the exposure of the insula to be the most consistent primitive feature of his series; Shellshear also emphasised this feature. Shellshear and Elliot Smith noted that despite the filling out of the temporal lobe and the narrowing of the temporo-cerebellar recess, the temporal eminence was still a marked feature of the brain. They have observed also the upward expansion of the parietal eminence; Shellshear had previously noted that the supra-marginal region, which constitutes this eminence, appeared to be the focal point of parietal expansion in the Bushman brain. The filling out of the parieto-occipital depression was noted also by these authors. Slome remarked on the "square-cut" form of the occipital pole.

All these points have been established as consistent features of this series and may be regarded as pathognomonic of the type. A number of other points have also emerged which have not been specifically noted by other observers. One of these is the downward deflection of the orbital rostrum and of the lateral orbital margin. Another, and more important, is the local area of expansion at the anterior extremity of the middle and superior frontal convolution. The comparison of coronal profiles has also brought out, more clearly than heretofore, the degree of relative expansion of the different frontal areas; the different rates of expansion of the upper and lower parietal areas have been similarly demonstrated. The lack of expansion of the temporo-occipital area has been emphasised for the first time. Finally the ill-defined and flattened form of the cerebro-spinal channels has been pointed out

Regarding the visual area, the findings of previous authors were discrepant. Whereas Slome found a well-developed lunate sulcus in a minority of his specimens, Shellshear observed it to be extraordinarily well-developed and extensive in Marshall's specimen. In the present series it has been found that this sulcus, while easily recognisable, is not very extensive; the primitive arrangement observed by Shellshear is not apparently characteristic of the Bush race.

With this exception, the primitive features of the Bush brain observed by Shellshear and enumerated above have proved to be consistent features of the present series of specimens. It may be concluded, therefore, that they are usual features of the Bushman brain, and are thus of genuine racial, as well as morphological significance. This is equally true of the features noted by Shellshear and Elliot Smith in the Bush endocranial cast.

We may, therefore, appraise the position occupied by the Bush brain in the scale of cerebral evolution. Compared with that of the European, it has been shown to fall short in many respects. These include the narrowness and shortness of the frontal lobes, the lack of expansion of the superior and middle frontal territories, the exposure of the insula and the shortness and lack of expansion of the temporal pole, the lateral projection of the

temporal contour anterior to the parietal eminence, the presence of distinct temporal and parietal eminences, the lack of expansion of the superior parietal and temporo-occipital areas. All of these points indicate the uneven development of both the frontal and the parieto-temporal association areas, whose progressive expansion is the cardinal feature of human cerebral evolution. Judged by these anatomical features, the Bushman must be considered definitely inferior in cerebral development to the European.

The small size of the Bushman brain is also considered to be an indication of inferior cerebral development. It must be borne in mind, however, that the Bushman is of dwarfish bodily build, so that relative to his body bulk his cerebral development is not so poor as the figures alone would suggest. Moreover, it is a commonplace observation that size of brain and mental powers are by no means closely related in any individual case, though on the average a relation between them can be established. *The small size of the Bushman brain, is, in fact, only significant in that it is the reflection of the defective expansion which the brain reveals.*

When, however, we compare the endocranial cast of the Bushman with those of primitive human types such as *Sinanthropus* and Rhodesian Man, it reveals in many points a definite advancement beyond them. This advance is seen in the expansion of the inferior frontal region and of the anterior extremity of the middle and superior frontal gyri; in the expansion of the inferior temporal gyrus, with the concomitant widening of the temporal pole and narrowing of the temporo-cerebellar recess; in the great outward and upward expansion of the parietal eminence; in the filling out of the parieto-occipital area; and in the relatively reduced extent of the visual area.

The endocranial cast of the Bushman, in fact, occupies a position almost midway between that of Rhodesian Man and that of the European; it represents a logical intermediate stage between the brains of the generalised early types of humanity and those of more advanced living races. The morphological significance which Shellshear recognised in Marshall's specimen thus belongs, not merely to the brain of an individual Bushman, but in large measure to the brain of the Bush physical type.

Comparison of the endocranial casts of Boskop Man with those of the Bushman have shown that the Boskop type is, in practically every feature studied, less developed than the Bush type, being intermediate between the Bushman and Rhodesian Man. Some of the variations found within the Bush series represent an approximation to the Boskop type. These may well be the result of hybridisation between the Bush type and the Boskop type, of which there is ample skeletal evidence. On the other hand, since the Boskop physical type and the Bush physical type are thought to have a common ancestry (Galloway, this JOURNAL,

p. 98) these variations may represent an ontogenetic reversion to an earlier stage in the evolution of the Bushman brain. One of these two explanations doubtless accounts not only for the variation in this series of casts, but also for those in other series, e.g. the primitive character of the lunate sulcus in Marshall's specimen.

Many anthropologists, however, have seen in the Bushman a peculiar specialisation of humanity, characterised by the retention or even exaggeration of the features of infancy and childhood. It is of importance, therefore, to ascertain how far the distinctive features of the Bush endocranial cast are those of a juvenile stage of development in other races.

Kappers' (1929) metrical analysis of the brain of European foetuses and newly-born infants shows that in the shortness of the frontal and of the temporal lobes the Bushman is comparable to these juvenile subjects. In the height indices and the steepness of the occipital slope, however, the European foetal brain lies at the other extreme from that of the Bushman, exaggerating the features of the brachymorphic type of brain.

For a comparison of the non-metrical features of the endocranial cast, the only infantile specimen at my disposal is that of a Bantu infant of three months. It is, of course, impossible to draw any dogmatic conclusions from a single specimen of potentially mixed racial origin, but the comparison of the non-metrical characters of this cast with those of the Bush type is worthy of remark. In addition to the downward deflection of the orbital margin and rostrum, whose significance as an infantile trait has already been pointed out, this cast shows a marked lateral projection of the inferior frontal region with a well-defined flattening of the upper and posterior frontal region. The temporal pole is not only short, but is isolated from the frontal lobe. The temporal lobe projects laterally beyond the fronto-parietal contour, and there is a distinct temporal eminence. This, however, is overshadowed by the salient parietal eminence, whose presence determines the pentagonoid contour characteristic of the "foetal" type of skull. This eminence is separated from the midline by an area of superior parietal flattening, while the parietal and temporal eminences are limited posteriorly by the parieto-temporal flattened area.

If this cast is fairly representative of the infantile type of brain cast, and there is no evidence that the morphological nature of the foetal brain is not common to all races, then it is true to say that the majority of the distinguishing morphological features of the Bushman brain are almost foetal in character. The brain of the Bushman is thus, in comparison with those of more specialised races, "foetalised." Such a result is not surprising, since, as Elliot Smith has pointed out, those regions of the brain which are unexpanded in Rhodesian Man, and whose progressive expansion can be traced in Boskop Man and the Bushman, are

the last to attain full functional development in the growth of the European child.

Finally, this study has shown how many features in the form of the brain case, which have been considered diagnostic of the Bush physical type, are directly dependent on the form of the brain. These include: in *norma verticalis*, the narrowness of the frontal region, and the prominent "foetal" parietal eminences which give the pentagonoid cranial form; in *norma lateralis*, the contour of the upper portion of the forehead, the anterior position of the vertex, the "infantile" curvature of the parieto-occipital region, besides the *mons temporo-sphenoidale* and the inferior frontal eminence; in *norma facialis*, the vertical sides and low flat roof of the frontal bone; in *norma occipitalis*, the flat vault and the supra-asterionic flattening or depression. Since these features are the outward expression of a characteristic cerebral morphology, it may reasonably be maintained that their racially-diagnostic value is at least equal to that of any characters, metrical or non-metrical, as yet proposed.

V—Summary of Conclusions.

1. A metrical and morphological analysis of eleven endocranial casts of known Bushman subjects (seven males and four females) has been carried out.

2. These specimens are all of small volume, confirming evidence previously available that the brain of the Bushman is among the smallest known in living races. The brain is characteristically elongated and narrow; the greatest parietal and greatest temporal diameters are approximately equal; the frontal region is short and narrow; the temporal region short; the highest point placed forward, producing a long occipital slope; the narrow frontal region has a quadrilateral outline; the parietal region flares out to laterally projecting parietal eminences, but in front of these the temporal region projects laterally beyond the parietal region.

3. The inferior frontal region and the anterior extremity of the middle and superior frontal gyri are expanded, while the posterior portions of the superior and middle frontal regions are, by comparison, unexpanded. The insula is exposed; the temporal pole is slender and widely separated from the under surface of the frontal lobe. The inferior temporal gyrus is expanded and the temporo-cerebellar recess narrow. There is a prominent temporal eminence. The inferior parietal region is expanded, with a salient parietal eminence, but the superior parietal region is depressed. The parieto-occipital region is evenly filled out, but the temporo-occipital region is flattened. The visual area is relatively small, forming a flattened tip to the occipital pole.

4. Comparisons with previous descriptions confirm these features as constant in the Bush type. The Bush brain is thus intermediate in its development between those of Rhodesian Man

and of the European. The available evidence regarding the nature of the endocranial cast of the phylogenetically related Boskop Man indicates that this type is more primitive than the Bushman, being intermediate between it and Rhodesian Man.

5. Many of the salient features of the Bush endocranial cast are reproduced in that of a Bantu infant. The Bushman brain may therefore be considered juvenile in its morphology. This observation is consistent with the fact that the regions which are incompletely expanded in the adult Bushman are the last to attain full functional development in the European child.

6. This study has shown that a large number of features of the Bush brain case are directly due to the form of the brain. It is therefore argued that such features have a special diagnostic value.

VI—Acknowledgments.

On behalf of the Department of Anatomy, University of the Witwatersrand, I have to thank Miss M. Wilman, Director of the MacGregor Memorial Museum, Kimberley, for the opportunity of preparing endocranial casts from skulls in the collection of that institution; also Professor T. F. Dreyer, of the Department of Zoology, in the University College of the Orange Free State, for the loan of the cast of the skull M.R. 1.

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PREHISTORIC ROCK PAINTINGS IN NORTHERN RHODESIA

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With 4 Text Figures and 4 Photographs.

Read 5 July, 1937.

1.—Introduction.

During a recent tour through Africa I was able to inspect certain hitherto unrecorded caves with prehistoric rock paintings in the Serenje and Mpika Districts of Northern Rhodesia. The invitation to visit these caves came from Mr. T. S. Fox-Pitt, the District Commissioner at Mpika, and I am most indebted to him as I am indebted also to Mr. F. M. Thomas, the Acting District Commissioner at Mpika during Mr. Fox-Pitt's absence, for their hospitality during my all-too-brief visit.

The caves are situated as shown in the map reproduced in Fig. 1. Unfortunately the time at my disposal was too short and the weather too bad to admit of an exhaustive or even very detailed investigation, but coming as these paintings do between the well-known and vast group south of the Zambesi and the group recorded by Leakey and others in Tanganyika and further north,* it is felt that these Northern Rhodesian occurrences should be placed on record.

The known distribution of prehistoric rock paintings in Africa south of the Sahara covers only that portion of the sub-continent that includes South-West Africa, the Union of South Africa, Mozambique, the Rhodesias, Nyasaland, Tanganyika and Abyssinia.† We have no record of paintings in West or Central Africa except those which may be referred to such tribes as the Masai, whose warriors, Dr. Leakey informs me, make a practice of painting the brand of the beast they slaughter for a feast on the wall of the cave or rock-shelter in which the feast is held.

* (1) *Stone Age, Africa*, Oxford, 1936, pp. 137-161. (2) Frobenius—Breuil: "Afrique," *Cahiers d'Art*, Paris, 1931.

† Breuil: (1) "L'Art Rupestres en Afrique," *Cahiers d'Art*, 1931. (2) "*Peintures Rupestres Préhistorique du Harrar*, Comptes rendus des séances de l'Académie des Inscriptions et Belles-Lethes, 1934, p. 226.

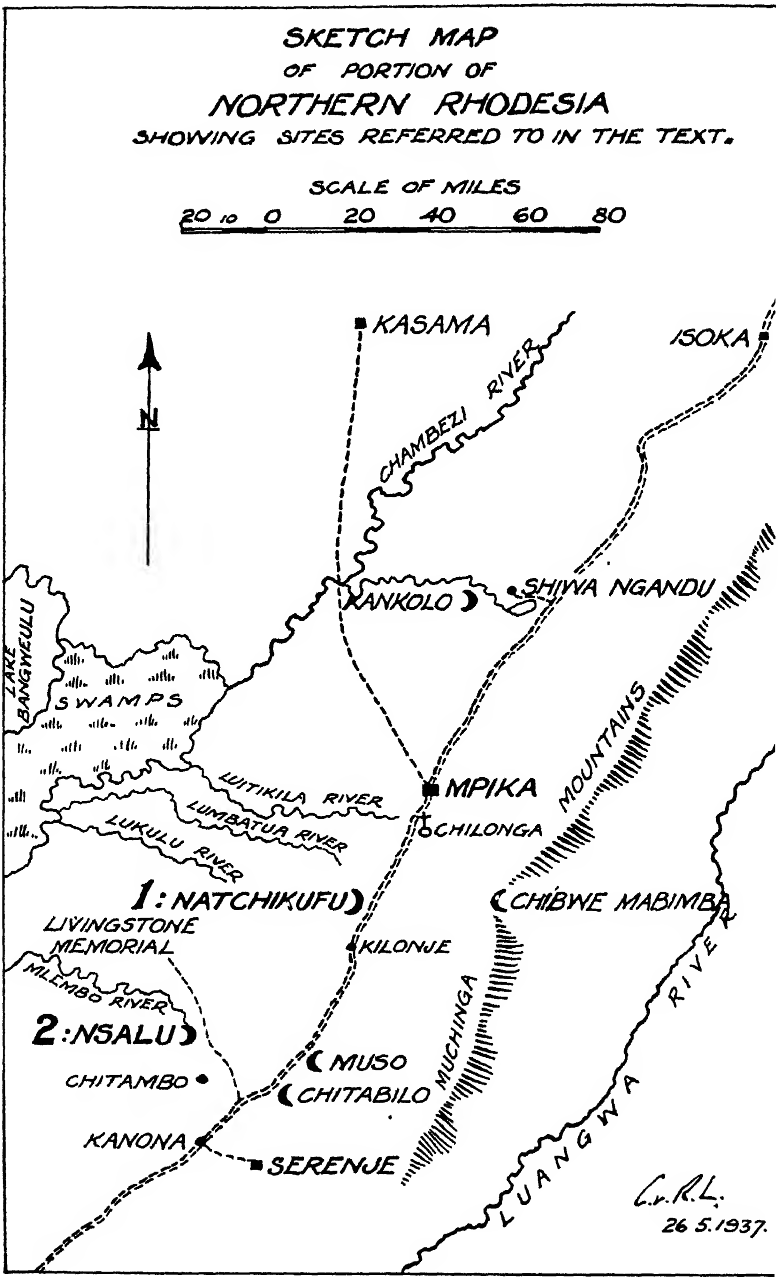

SKETCH MAP
OF PORTION OF
NORTHERN RHODESIA
SHOWING SITES REFERRED TO IN THE TEXT.
SCALE OF MILES
20 10 0 20 40 60 80
N
KASAMA
ISOKA
CHAMBEZI RIVER
KANKOLO
SHIWA NGANDU
LAKE BANGWEULU
SWAMPS
MOUNTAINS
LUITIKILA RIVER
LUMBATUA RIVER
LUKULU RIVER
MPIKA
CHILONGA
1: NATCHIKUFU
LIVINGSTONE MEMORIAL
CHIBWE MABIMBA
KILONJE
MLEMBO RIVER
2: NSALU
MUCHINGA
MUSO
CHITABILO
CHITAMBO
KANONA
SERENJE
LUANGWA RIVER
C.v.R.L.
26 5.1937.

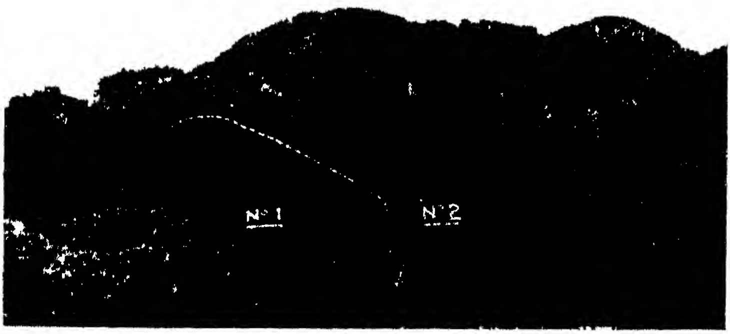
Fig. 1.

These brands are usually of a diagrammatic or schematic nature. In Uganda Mr. E. J. Wayland has a record of over six hundred caves and rock shelters, but he has neither noted nor heard of any rock paintings in that territory.

It would therefore seem that in Africa there exists an unbroken channel of occurrences of rock paintings that stretches from the Cape of Good Hope to the southern shores of Victoria Nyanza, where it is deflected to the east and reappears in Abyssinia, whence it continues on to the Sudan, the Libyan and Sahara Deserts and across North Africa into Spain. Numerous records exist of prehistoric rock paintings in all the territories that combine to make this channel except Northern Rhodesia, and it is felt that the filling of this gap will be appreciated. This area and Nyasaland combine to form an extremely important corridor and link in the greater channel along which similar occurrences have been noted. In certain areas the channel meanders somewhat; in others it is still obscured—by vegetation here, by deserts there—but I have little doubt that the day when most, if not all, of its obscurities will be cleared is not far off. Before considering these larger issues, however, let us see what a superficial examination of Northern Rhodesia has revealed.

2.—Description of Paintings.

A. *Natchikufu.*—At Natchikufu there are two main caves. These are shown in Photograph 1. That on the left (Cave No. 1



Photograph No. 1 showing Caves at Natchikufu.

No. 1 Cave is on the left almost wholly obscured by trees.

No. 2 Cave is on the right with figures at the entrance.

—somewhat obscured by trees) has a semi-circular entrance about 20 feet wide across the floor under the drip line, 14 feet high and tapers back for a distance of about 80 feet. It would, therefore, provide an excellent home for any primitive folk.

That this cave was occupied recently is abundantly proved by a marked deposit of ash, broken bones, remains of food, pottery, ore and slag, not only in the cave but also in its immediate vicinity. The occupants were probably a Bantu-speaking tribe, whose fires unfortunately blackened the roof and walls of the cave to such an extent that the rock paintings of the earlier (Stone Age) occupants have been almost entirely obliterated.

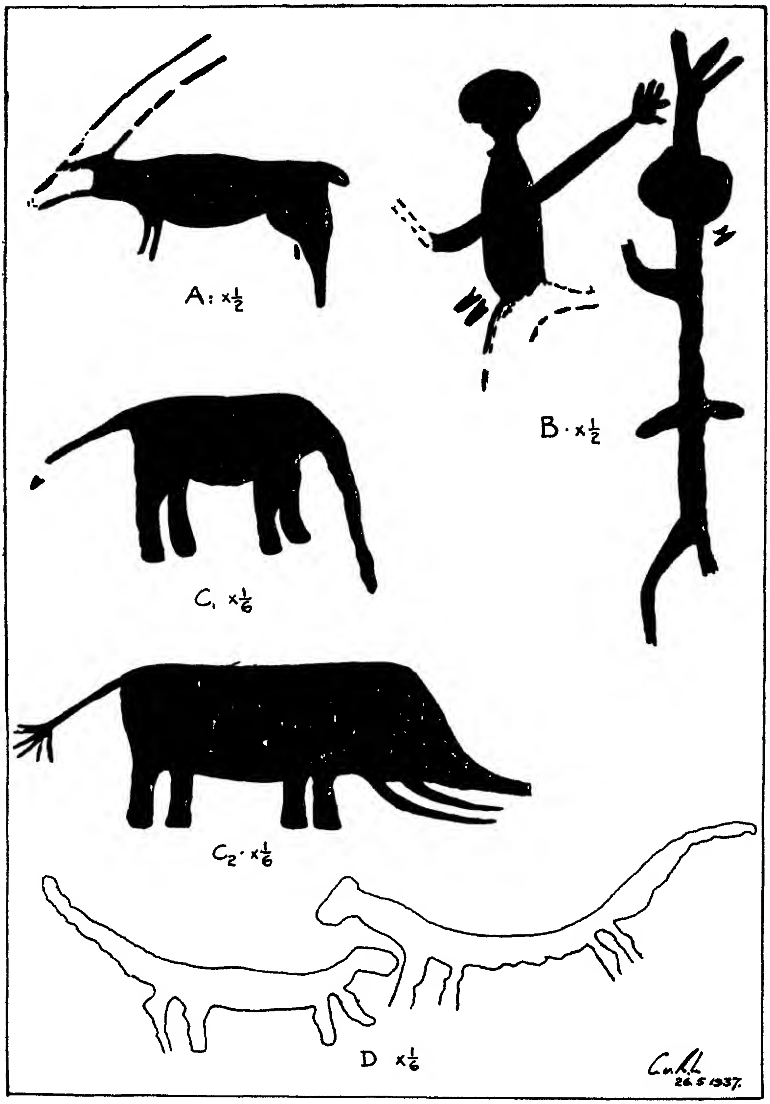


Fig. 2.

When he originally wrote to me about these caves, Mr. Fox-Pitt mentioned that they had been used by the Babisa as refuges from the Angoni raiders. However, under the soot and crude drawings of these native occupants there is much evidence of earlier occupation in the form of typical prehistoric (so-called "Bushman") paintings. Unfortunately these have been considerably damaged, and the work of the earliest artists has been almost entirely obliterated. Only two colours were used: black and white. The series is: old, black; recent, black and white.

Series 1.—The oldest paintings (black) are best represented in an antelope, possibly two elephants and a few humans illustrated in Fig. 2.

The antelope is only one inch above the floor on the right wall near the entrance. The most interesting feature about it is that the whole figure is coloured except the face, which is drawn in outline only with the middle left blank. This treatment corresponds to that practised in the earliest cave paintings in Tanganyika as recorded by Leakey* with this difference, that whereas the Natchikufu specimen is in black, the Tanganyika series is in red. Nevertheless, the fact that the painting is within an inch of the present floor level, which represents the top of an entirely artificial deposit, is a certain indication of its relatively great age. It is a typical "Bushman" painting in a free naturalistic style. In comparison, the elephants are badly drawn. One of the human figures is more diagrammatic and may belong to a different period.

Series 2.—Over these figures there are many others—blurred and indistinct. The vast majority are much later in age but still in black.

Series 3.—A few late and very degenerate figures in dirty white occur also. These (Fig. 2, D) are almost certainly the work of recent or comparatively recent occupants. The natives with us referred to the white paint (which appears to have been applied with the finger) as "pemba." They may represent attempts to copy the work of earlier artists—or they may not, We cannot be sure.

In No. 2 Cave—that on the right in the photograph—there are several schematic paintings in vermilion (Lefranc, Série F. No. 1431), red and orange weathered variations of the vermilion *under* the "pemba" or native (?) white, as well as a few figures in black also under the same ("pemba") white.

It would appear that the vermilion, red and orange paintings (mainly tectiform), represent a distinct series spoilt by weathering and over-painting by recent (native) occupants. The most interesting picture in the older (vermilion) series is shown in

* *Stone Age, Africa*, Oxford, 1936, p. 152.

Fig. 3. It measures $15\frac{1}{2}$ in. × $12\frac{1}{2}$ in., and is interesting on account of the asymmetrical design it embodies.

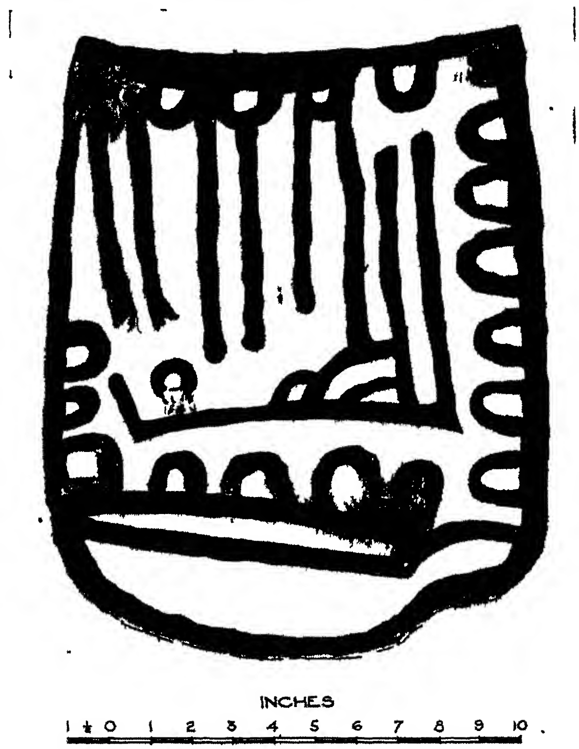


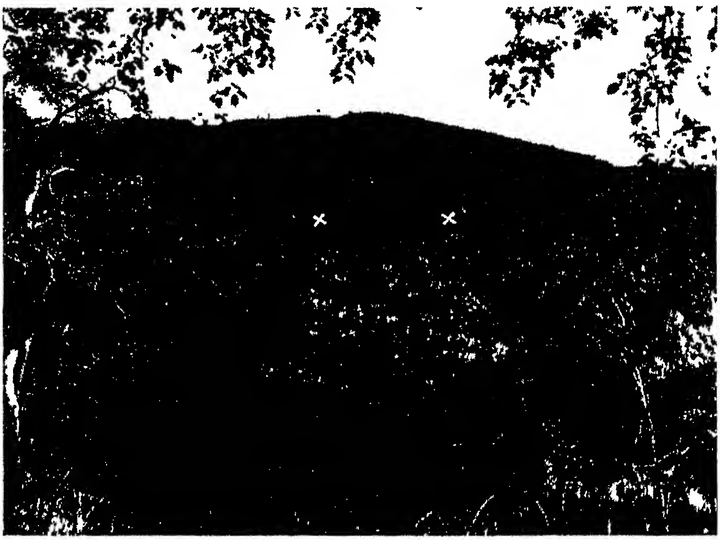
FIGURE 3.

I sent a copy of the figure reproduced here to Mr. H. J. Braunholtz at the British Museum and asked him to submit it to an expert. I thought it might be a cartouche. Mr. Braunholtz replied as follows:—"In your second figure (cartouche from Northern Rhodesia) the central 'glyph' is regarded by our expert as undoubtedly a debased version of the word 'Allah' in Cufic (Arabic) lettering, and might date from the 12th century A.D. or later. It should be written thus: $\underline{\nabla \quad |||}$. The surrounding portions cannot be interpreted though their general appearance suggests Cufic in a debased form. As you probably know, in North and West Africa, as in Asia, Arabic writing is frequently debased into meaningless decorative patterns."

This information is extremely valuable, as it obviously gives us some idea of the age of this particular painting and the series to which it belongs.

There can, however, be no doubt that both these caves were occupied by Stone Age folk. The floors as well as the ground in the immediate vicinity of both are littered with flakes and chips in clear and cloudy quartz. I had no time for more than a superficial examination, but I was greatly impressed by the archaeological potentialities of the site.

B. *Nsalu.*—The main Nsalu Cave, shown in Photograph No. 2, is about 50 feet wide along the floor under the drip line, about 20 feet high and 20 feet deep. As in the case of Natchikufu, there is considerable evidence of occupation during the Stone Age both in and in the immediate vicinity of the cave.



Photograph No. 2 showing Nsalu Cave. The cave lies between the white crosses.

It has been known for a number of years, and a photograph of some of the paintings appears opposite page 198 in J. E. Hughes' book "*Eighteen Years on Lake Bangweulu.*" The walls of the main shelter contain a considerable fresco of pseudo-geometric or schematic paintings that reveal the following colour sequence:

(1) Yellow *under*, (2) red and white (used both separately and together) *under*, (3) white *under*, (4) dirty white or grey, as well as isolated designs in brown and recent erratic markings and one elephant in black.

Series 1: Yellow.—The oldest series is in yellow. It includes designs both above and below a broad yellow band some four inches wide and about 40 feet long, commencing on the left of the shelter (as one looks inward) and 12 feet to 14 feet above the

ground. The designs include vertical and horizontal bands, lines, concentric rings and circles, crescents, ladders, elongated U's or "hairpins," shields (?) or aprons (?), a hand and a mass of irregular markings Without exception all paint seems to have been applied with the finger

Photograph No 3 shows the broad yellow band and a few of the figures referred to very clearly, but the majority are so indistinct as to be quite beyond photographing. Fig. 4 gives a fair idea of the types of designs depicted. Unlike Figs. 2 and 3, these are from sketches, not tracings.

Photograph No. 3 showing interior (left wall) of Nsalu Cave

Series 2 Red and White.—Both red and white (whether used separately or in the same design) occur *over* the yellow. The artists in red seemed to specialise in elongated U's or "hair-pins." There are hundreds of examples with an average length of six inches drawn in lines ½ inch or so wide—the whole again apparently applied with the finger. The type of design is sketched in Fig. 4.

Photograph No 4, which shows the wall on the right, is opposite the view depicted in Photograph No. 3. The white U's, etc., show up very clearly, but not the red. The black elephant on the right is a recent contribution in charcoal.

Series 3: White.—In addition to the *red* and *red and white* figures there are many white dots arranged in horizontal and vertical lines or in irregular ellipses—the whole again apparently applied with the tip of the finger. See Fig. 4.

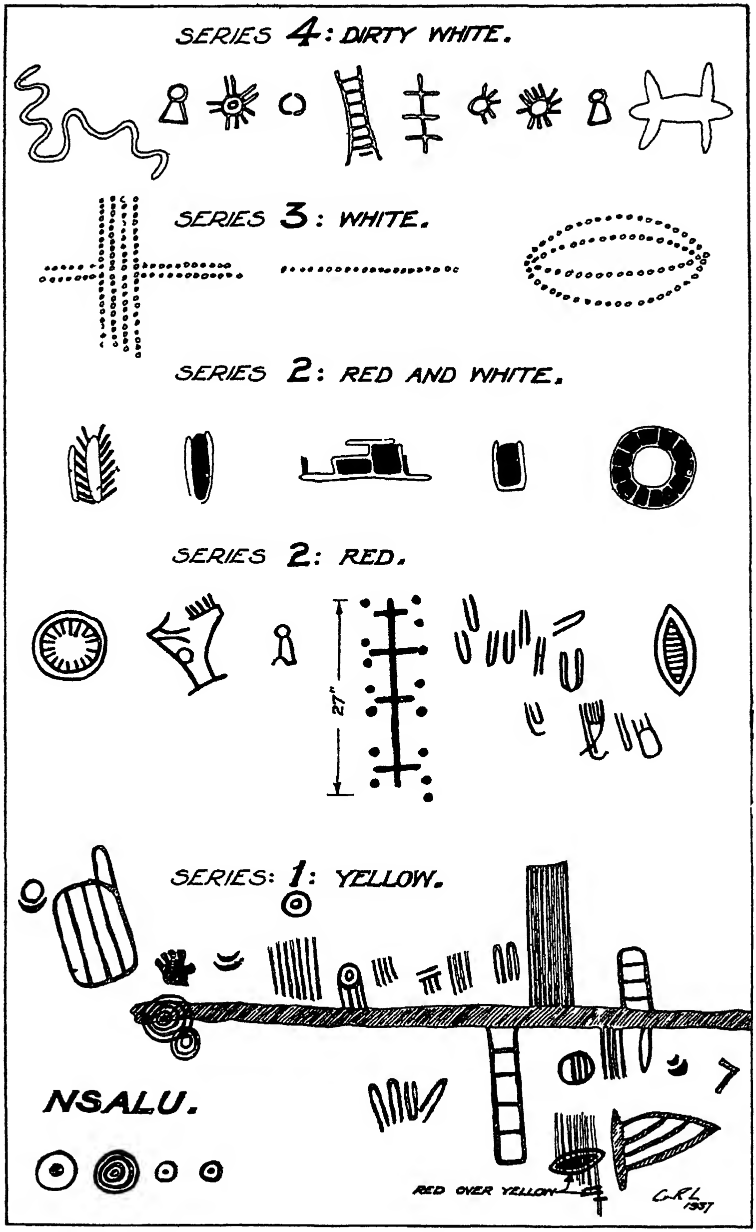

SERIES 4: DIRTY WHITE.
SERIES 3: WHITE.
SERIES 2: RED AND WHITE.
SERIES 2: RED.
27"
SERIES: 1: YELLOW.
NSALU.
RED OVER YELLOW
G.R.L. 1937

Fig. 4.

Series 4: Dirty White or Grey.—This, the last of the series, includes imitations of the older work as well as three figures that resemble stretched hides, a snake-like figure, several halma-men, and a few "sun-spots" illustrated in Fig. 4.

Photograph No. 4 showing interior (right wall) of Nsalu Cave.

3.—Stone Implements.

All that a superficial examination of the remains in and in the immediate vicinity of the caves tells us is that before Bantu-speaking people appeared on the scene the area was most probably occupied by a Stone Age folk who practised a microlithic industry.

The occurrence of bored, grooved and grind stones, as well as of polished stone axes of Neolithic facies, has been noted in

the vicinity of the caves indicated in both the Serenje and Mpika districts. While this may have little or nothing to do with the rock paintings, we know that it was during the age when such tools were made that rock painting was in vogue in other areas, and my reason for mentioning these occurrences is that they should be borne in mind in any future investigation of the caves. It is possible that there were three groups of artists: (1) a Bushmanoid group in a palaeolithic stage of development expressing themselves in a free naturalistic style, (2) a later group with a material culture that included neolithic elements and a schematic art, and (3) the Bantu-speaking tribes who followed with superimposed copies of the earlier paintings and perhaps a little original work of their own.

The presence of a culture related to the Smithfield or Wilton which we have every reason to associate with the art of rock painting in Southern Africa has to be proved, and can only be proved by systematic excavation. Bored, grooved and grind stones and the nature of the factory-site debris at these caves suggest the presence of one or the other (or both) of these cultures. I recovered a fragment of a grooved stone near a rock shelter in the Muso Hills, and noted repeated occurrences of bored stones in both the Serenje and Mpika districts. Where the land has been cleared and prepared for cultivation, as it has been on Lieut.-Colonel the Hon. S. Gore-Browne's delightful estate at Shiwa Ngandu, near Kankolo, several bored stones have been found.

These discoveries suggest a link between the earlier naturalistic artists of Natchikufu, for example, with those of the great group south of the Zambesi—those who were responsible for the so-called " Bushman " paintings that depict animals in the best naturalistic style—as well as with those whose works have been noted in Tanganyika.

Polished stone axes have been found in a cave at Nachichingo, about three miles south of Nsalu. Two specimens have been recovered in the vicinity of rock shelters in the Chini Hills, some 30 miles north of Kanona and 1½ miles west of the Great North Road—and therefore not far from Natchikufu—while further specimens have been found in the vicinity of the Velocity Gold Mine, some 60 miles north of Mkushi Boma on the old mail road to Serenje. These occurrences may have nothing to do with the rock paintings, but when one considers the extraordinary affinities that exist between the later schematic paintings at Natchikufu and those at Nsalu with the neolithic art of Spain, one should bear these occurrences in mind in any more exhaustive enquiry than I was privileged to undertake.

In passing, it should be noted that in his description of the Nsalu cave Mr. Hughes says:—" The cave in soft white quartzite is about one hundred feet long and eighteen to twenty feet high. Prehistoric flint *(sic)* implements are to be found

there in profusion; also round stones with a hole through the middle of each. . . . There are piles of flint cuttings *(sic)*. Croad made a superficial search, not having much time to spare. He picked up one stone axe, and before leaving took a photograph of the walls, which are covered with ancient paintings and signs in black, white and red."*

This description is not very accurate, but it is the only printed reference I have been able to trace, and the mention of stone implements, especially the " axe," is illuminating.

4.—Discussion.

Certain of the Natchikufu paintings (most notably the antelope and humans in Series 1 from Cave No. 1) are typical of the work of the Bush folk. The antelope is in the free naturalistic style of the older period of rock painting in South Africa.† This, the oldest series of paintings, thus provides another link in the chain of events that led artists of the palaeolithic age into such continental extremes as South Africa and Eastern Spain. We find their paintings throughout Southern Africa, in Tanganyika, in Abyssinia, in North Africa and in Eastern Spain, and it would appear to be only a question of time before the intervening spaces are filled.

The little we know of the material cultures we have been disciplined to associate with these early artists strengthens our suspicions of a widespread diffusion of our upper palaeolithic forerunners. But much requires to be done—even at Natchikufu. The deposits in the cave need to be systematically examined. That such examination will yield rich results I have no doubt. If excavation reveals a Wilton industry, for example, we shall have an additional reason for accepting a Bushmanoid artist for the earliest naturalistic paintings, but, if not, we shall have to go further. The presence of bored, grooved and grind stones, as well as of flakes and chips, that suggest a microlithic industry in the area is rather suggestive.

When we proceed to an examination of the vermilion paintings at Natchikufu Cave No. 2, and those included in Series 1, 2 and 3 at Nsalu, we find we are in contact with something entirely different. No longer is the art naturalistic (either good or bad), but entirely schematic. We find we are in contact with such paintings as have been reproduced by the Abbé Breuil in the four magnificent volumes that deal with "*Les Peintures Rupestres Schématiques de la Péninsule Ibérique*," published by the *Foundation Singer-Polignac* during the years 1933-1935. The resemblance between the paintings of the Spanish neolithic age and those from Northern Rhodesia can only be described as

* *Eighteen Years on Lake Bangweulu*, p. 198.

† van Riet Lowe: *An Illustrated Analysis of Prehistoric Rock Paintings at Pelzer's Rust.* *Trans.Roy.Soc.S.Afr.*, Vol. XX, pt. I, pp. 51-56, 1931.

astonishing. No matter what figures we select from the latter—whether they depict ladders, circles (concentric and single, with or without lines that radiate regularly or irregularly from the outer circle), crescents, pectiform (comb) types, arrangements of dots, lines and elongated U's or hairpins, figures shaped like halma-men, etc., we find their counterparts in Neolithic Spain. This similarity is most striking when we compare Fig. 4 with Plates Nos. XIX, XX and XXI of Volume I *(Au Nord du Tage)*, but the same applies to practically all the figures that do not depict humans or animals of the remaining volumes, not only in Spain but also in the Sudan and Mozambique. Is this another though later link between the extremes we are considering, or do these remotely situated frescoes merely reflect an inevitable evolution of art from its unfettered, straightforward, naturalistic beginnings to the more complicated schematic or conventionalised climax? These are questions from which we cannot escape. The remarkable affinities reflected first in the art of the palaeolithic age and later in that of the neolithic are inescapable, despite the immense spaces that separate the two centres we are considering—Spain in the north, Rhodesia in the south.*

I have drawn attention to the presence of polished stone axes in Northern Rhodesia. These and pottery form merely two of the elements that reflect a neolithic stage of development. A few years ago we had no record of neolithic elements in

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* Since the above was written, Mr. F. M. Thomas has sent the following note to me from Mpika: "I have been looking again at your drawings of the paintings in Nsalu Cave. The concentric circles are very similar to the drawings that used to be made and still are among the more conservative people here for the *Chizungu* or formal marriage of a young girl to her husband. The husband is invited to shoot at marks made on the wall. These marks are usually concentric circles or 'bull's-eyes,' and he is expected to hit with his arrow the centre of any other line pointed out by the elders. Such drawings are known as *Mbuza*. Nowadays they are drawn on the walls of huts, but the bridegroom is not often called upon to shoot.

"Before the actual marriage the bride-to-be undergoes a course of instruction, during which old women tell her about dangerous animals which she should avoid. In order to impress these on her memory, clay models of lions, snakes, etc., are often made and covered with hair, beads, grass, etc., to make them awful to behold. Sometimes these animals are drawn instead of being modelled, and I think that some of your snakes and other objects were drawn by Bantu people for this purpose.

"Anyway, your antelope wouldn't fit into this scheme at all, as it would never be drawn as an *Mbuza*, which is another piece of evidence to show (I think) that it belongs to a different age and culture. I am not sure about the elephants. The natives I have asked have been doubtful whether or not such drawings would be *Mbuza* (i.e. using that term to cover all drawings made in preparation for the marriage, whether for the man or for the woman), but most of them say elephants might be *Mbuza*."

This information is new to me and needs to be carefully weighed in any attempt that may be made to correlate the latter (Neolithic-type?) paintings with similar occurrences elsewhere.

Southern Africa, to-day we have records of polished stone axes in the Cape of Good Hope, the Transvaal, Southern Rhodesia, Northern Rhodesia, Equatoria (West and East Africa), Abyssinia and so north to palaearctic regions. When we consider these slender ties between such far-flung occurrences of the Neolithic Age alongside the firmer ties that knit all Africa and much of Europe and Asia into a great whole of human activity during the preceding ages—the Palaeolithic and the Mesolithic—and then pass on to a consideration of the elements that link this whole during the succeeding ages, we see our continent as a vast stage upon which the movement of man has continued with little interruption throughout the ages. The deeper we probe, the more do we realise that the strangeness of apparent affinities that perplex us to-day becomes the accepted commonplace of to-morrow.

A close and accurate observer recently said: "Thère is much greater movement of Africans over the face of Africa than most people realise."* This may well be altered to: "There has always been much greater movement of man over the face of Africa than most people realise."

5.—Conclusion.

The technique employed for copying the paintings illustrated in Figs. 2 and 3 was as follows:—With the aid of indian ink and a brush the original was first traced on a sheet of "Cellophane." To do this one needs at least one assistant to help hold the "Cellophane" against the rock. The transparency of this material makes it much more effective and desirable than any tracing cloth or paper I have tried. If one handles and stores it properly one need have no fears about tearing or otherwise damaging it. It should be kept in a stout cardboard or metal tube—just as one keeps other paper used for the same purpose.

The original tracing is then transferred to tracing cloth for permanent record and a copy (also on tracing cloth) made for the printer, who handles this as easily and as satisfactorily as he handles a drawing on paper, canvas or board.

The figures used here are therefore reproductions of tracings (on cloth), of tracings (on "Cellophane") of the originals. The margin of error is thus reduced to a minimum.

In conclusion, I wish to record my indebtedness to Captain E. C. Mills, big-game hunter at Kanona, for having taken me to the Nsalu Cave and for having given me much valuable information about occurrences of polished stone axes, bored, grooved and grind stones and pounders in the Serenje and Mpika districts. To Mrs. Grace Gore-Browne, of Shiwa Ngandu, I am also indebted for information about similar occurrences in the Mpika and Chinsali districts, as well as for her generous hospitality during my all-too-brief visit.

* Julian Huxley: "Africa View," p. 71.

South African Journal of Science, *Vol. XXXIV, pp. 413-415, November, 1937.*

A NOTE ON SOME UNUSUAL BEADS FROM SOUTHERN RHODESIA

BY

G. F. Berry,

Department of Anatomy, University of Witwatersrand.

With 2 Text Figures.

Read 5 July, 1937.

The object of this note is to place on record some beads of a type hitherto undescribed from Southern Rhodesia.

The beads were surface finds on a steep hill, difficult of access, and isolated in otherwise rather flat country in the Essexvale district This hill is known locally as Mount Alice. That its summit was once occupied is revealed by the presence there of stone walls and clay floors, all in a very ruinous condition. Scattered over the hill is a great profusion of potsherds and other relics of habitation, among which were found the beads of clay and glass and the stone pendant described below. The existence of this site has been intimated to Mr. Neville Jones, Director of Archæology for Southern Rhodesia, who intends investigating it more thoroughly in the near future.

Clay Beads.

The two clay beads differ somewhat in size and shape, but texturally are the same. They are both of coarse brownish clay, and, judging from the hardness of their consistency, have been fired after the manner of clay pots. In form they are both rather rough, and have a perforation about 2 mm. in diameter.

One of these is nearly spheroid (Fig. I., 1), though slightly broader than it is high, the height being 1·5 cm. and the breadth 1·7 cm. There is an indentation at one end leading down to the perforation, which is through the smaller of these diameters, and is slightly eccentric in position.

The second is roughly barrel-shaped (Fig. I., 2). Its height is 1·9 cm. and its diameter 1·5 cm. It is perforated through its greatest length.

Glass Beads.

These are three in number, and are of varying shades of blue, and differ in the texture of glass from which they are made.

The first consists of half a roughly spherical bead, with a diameter of just under 1 cm. The ends of the bead are slightly

flattened. It is made of clear, though not absolutely homogeneous, glass, dull royal blue in colour.

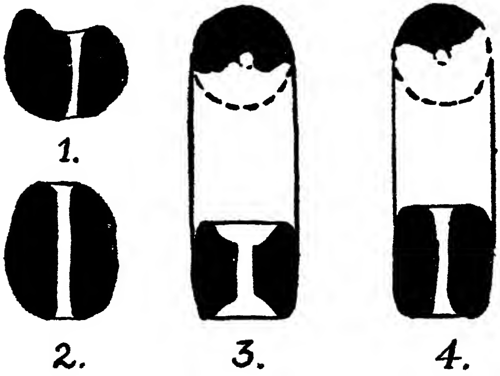

Fig. I.

The shape of the second is nearly cylindrical. Each end of this bead is indented by a conical depression leading down to the perforation (Fig. I., 3). It is 1·3 cm. high, and of the same breadth. The glass in this case is also clear but not homogeneous, and is of a deep sea blue colour.

The third bead (Fig. I., 4) is incomplete, but has been cylindrical in shape and about 1·5 cm. high with a slightly smaller diameter. It is made of opaque and rather granular glass, light blue-green in colour, being almost identical in colour, texture and shape with the so-called "Garden Roller" beads from Mapungubwe.

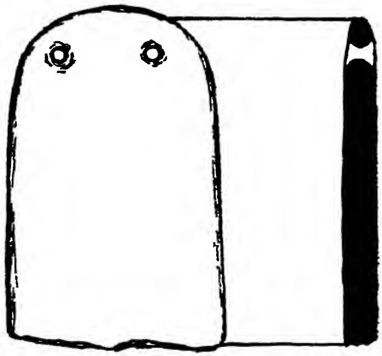

Fig II.

Stone Pendant (Fig. II).

This is a flat piece of greyish-green shale, roughly quadrilateral in shape. One end is missing, while the other is rounded off. The existing length is 4·5 cm. and the breadth 3 cm. The edges and surfaces are smooth, flat and polished. Near the rounded end are two perforations for suspension; both of these are hour-glass in shape.

The clay beads, previous description of which I am unaware, have no counterpart in modern " Bantu " culture. Their general appearance, however, suggests that they are crude imitations of glass beads.

The cylindrical or " Garden Roller " type of blue-green glass bead has previously only been described from those excavated at Mapungubwe, examples of which were shown to me by Professor C. van Riet Lowe, Director of the Bureau of Archæology, and Director of Field Operations for the Archæological Committee of the University of Pretoria. These beads were found at depth, and are thought to be of considerable antiquity. That they should have occurred as surface finds at this site is therefore of interest, as the one example is almost indistinguishable from the Mapungubwe beads, while the other appears to be a variation of the same type.

The stone pendant resembles examples from various sites in South Africa, which have been always associated with Late Stone Age implements, and not with a " Bantu " culture, as was this one. It does resemble in some respects, however, two objects described in " Zimbabwe Culture," by Caton Thompson, from the Hubuvumi ruins. These, however, are both made of pottery, and have only one perforation; one of them, also, has lines engraved on one of its surfaces. They are thought to have been used as divining dice, whereas the object described above seems much more likely to have been used as a pendant.

Acknowledgments.

I am very grateful to Mr. and Mrs. Richardson for their kindness to me during my stay at Essexvale, and also to my guide, Miss Stella Richardson, who drew my attention to the site.

South African Journal of Science, *Vol. XXXIV, pp. 416-436, November, 1937.*

DIE BUSCHMÄNNER SÜDWESTAFRIKAS UND IHRE WELTANSCHAUUNG

VON

Dr. H. Vedder,
Praeses der Rhein. Mission, Okahandja, S.W.A.

Am 6. Juli 1937 gelesen.

Den Geologen interessieren in Suidwestafrika vor andern Gesteinsarten die Granitfelsen, die hier ohne Wegräumungsarbeiten studiert werden können; denn sie sind die ältesten Zeugen der erdgeschichtlichen Vergangenheit.

Der Botaniker ist glücklich, wenn er in der Namib eine Welwitschia mirabilis findet, eine Pflanze, deren Geschichte in ferne Jahrtausende zurückweist.

Der Zoologe freut sich, wenn er in Südwest im Kaokovelde und anderswo in der Freiheit der Natur Elefanten, Rhinozerosse und Giraffen erblickt. Er nennt sie überlebende Reste aus der Urgeschichte der Erde und ihrer Fauna.

Der Völkerkundige aber hofft in Südwestafrika lebendige Buschmänner vorzufinden. Er ist geneigt, in ihnen nicht nur Vertreter der Urbevölgerung Afrikas zu sehen, sondern auch einen Menschenschlag, unter dem man studieren kann, wie etwa das Leben des Menschengeschlechtes und sein primitives Denken sich in einer Zeit gestaltet haben mag, aus der uns keine geschriebenen Erinnerungen aufbewahrt sind.

Wenn ich Ihnen daher heute " von den Buschmännern Südwestafrikas und ihrer Weltanschauung " berichten darf, so ist mir das Ehre und Freude zugleich, und ich hoffe, dass mein Bericht Ihnen keine Enttäuschung sein wird.

Es haben zwar schon viele ernste Buschmannforscher über dieses im Aussterben begriffene Völkchen geschrieben. Es ist nicht erforderlich, hier die Namen der verdienstvollen Männer und Frauen aufzuzählen. Sie sind Ihnen bekannt. Wenn ich es aber wage, Ihnen einen Vortrag über die Buschmänner zu halten, so geschieht es in der Ueberzeugung, dass ich dem bereits Bekannten einiges Neue hinzufügen kann. Ich hatte das Glück, etwa zehn Jahre meines Lebens in unmittelbarer Nähe einer Buschmanniederlassung leben zu dürfen. Daher hatte ich reichlich Gelegenheit, ihre Sprache, Sitten und Gebräuche und besonders ihre Geistesprodukte studieren zu können. Es war dies in Gaub, einer Farm in dem Dreieck Otavi-Grootfontein-Tsumeb. Dort wohnten seit alten Zeiten Buschmänner vom

Stamm der Saan, und dorthin zog ich nach und nach eine Buschmannkolonie vom Stamm der !Kû zusammen. Sie zählte 56 Personen.

In meinen Ausführungen werde ich aber nicht auf meine Forschungen unter den Saan eingehen, sondern mich lediglich an die !Kû-Buschmänner halten. Ich weiss wohl, dass einige Forscher kaum einen Unterschied zwischen Saan und !Kû machen. Buschmann ist ihnen eben Buschmann. Ich halte das aber für irreführend. Dafür habe ich folgende Begründung anzuführen.

Die Saan-Buschmänner bewohnten seit alten Zeiten den westlichen, nördlichen und südlichen Teil von Südwestafrika. Man findet sie heute noch vereinzelt im Ambolande, wo einst die Häuptlinge ihre Leibwachen aus den Saan zu rekrutieren pflegten, und diese als Scharfrichter bei den überaus zahlreichen Todesurteilen der Ovambokapitäne gebrauchten. Man findet sie in der Steppe zwischen Amboland und Tsumeb, im Bezirk Outjo und anderswo. In geschichtlicher Zeit noch hatten sie die Namib inne, wohnten in den Bergen des Oranje und an fast jedem Ort des Namalandes konnte man auch Saan vorfinden. Der bekannteste Stamm dieses ausgebreiteten Volkes der Saan sind die Hei – ||omn = Buschschläfer. Den Namen erhielten sie, weil sie entgegen der Gewohnheit anderer Eingeborener nachts nicht auf freiem Felde schliefen, wenn Jagd oder Reise sie von der Niederlassung fern sein liessen, sondern sie schliefen im Gebüsch, ungeachtet der Gefahren, die dem Buschschläfer drohen, da er herannahende Gefahren nicht rechtzeitig erkennen kann.

Diese Saan wohnten vor 200 Jahren sogar noch zum Teil in der Kapprovinz. Auf den alten Karten finden Sie dort ein weites Gebiet, das damals den Sanqua ober Sonqua gehörte. Nur die verschiedene Schreibweise lässt uns diesen Tatbestand nicht ohne weiteres erkennen. Es ist aber nicht richtig, was Dr. Th. Hahn van diesen Saan sagt, dass sie nämlich die Urbevölkerung des Landes darstellen, und das dies aus ihrem Volksnamen und seiner Deutung hervorgehe. Er leitet den Volksnamen " Saan " ab von dem Namawort *sâ*, ruhen, sich irgendwo niederlassen. Hätte er richtig gedeutet, dann müsste aber der Name mit einem Nasal ausgesprochen werden. Das geschieht jedoch nirgendwo. Von jedem Nama kann man daher hören, dass dem Volksnamen das Zeitwort *saa* zugrunde liegt. Dies bedeutet " auflesen, auslesen." Saan sind also die Auflesenden, die Sammler, die von den Früchten der Sträucher und Knollen der Erde leben, die sie auflesen müssen, im Gegensatz zu den Hottentotten, die das nicht nötig hatten, da sie Viehzüchter waren und von ihren Herden lebten.

Im übrigen stehen die Saan den Hottentotten sehr nahe. Das hat nicht nur die Blutuntersuchung bewiesen, sondern es kommt noch manches andere dazu. Die Saan sprechen die Sprache der Hottentotten mit geringen dialektischen Verschie-

denheiten, sie haben nahezu denselben Fabelschatz, den die Hottentotten haben: wer die alten Sitten und Gebräuche, die unter den Hottentotten nahezu unbekannt geworden sind, studieren will, kann daruber viel unter den Saan erfahren. Was Dr. Kolbe vor 200 Jahren am Kap unter den Hottentotten beobachtete, lässt sich heute noch unter den Saan erfragen. Dies genüge um darzulegen, warum ich in meinen Mitteilungen mich auf die Saan und Hei – ǁomn nur nebenher beziehen werde.

Oestlich von den Saan im Sandvelde, in der Kalahari und im Kau-kauvelde wohnen andere Buschmannstämme. Zu ihnen gehörten die !Kû, die zu beobachten ich Gelegenheit hatte. Sie sind durchgehends kleiner als die Saan und sprechen eine Sprache, die sich von der Sprache der Hattentotten und Saan wie Deutsch von Chinesisch unterscheidet. Zwar verfügen beide Sprachen über Schnalzlaute, und zur Sinnunterscheidung gleichlautender Worte bedienen sie sich verschiedener Tonhöhen; aber eine eingehende Untersuchung zeigt, dass die Schnalzlaute in der Sprache der Hottentotten und Saan den Buschmannsprachen entlehnt sind, und dass die ursprüngliche Sprache dieser Völkerschaften keine Schnalzlaute besass. Zudem ist die Namasprache sehr Formenreich, und der Aufbau eines Satzes erfolgt nach sehr verzwickten Regeln. wahrend die Sprache der Kalaharibuschmänner über äusserst wenig Formen verfügt.

In Südwest werden drei Dialekte dieser einfachen Buschmannsprache gesprochen. Am Kap wurde in alten Zeiten noch ein vierter gesprochen, denn dieser Buschmannstamm, den wir jetzt nur noch in der Kalahari finden, hatte früher seine Verwandten auch in der Kapprovinz. Während die Saan in den Niederungen als Jäger und Sammler lebten, während die Hottentotten ihre Herden auf den Ebenen weideten, bevölkerten diese echten Buschmänner die Berge und Schluchten und waren der Schrecken der Hottentotten und europäischen Ansiedler durch ihre Viehdiebstähle und Räubereien. Man unterschied deshalb bald am Kap zwischen den zahmen Buschmännern, die zum Stamm der Saan gehörten, und den wilden Buschmännern, deren Weltanschauung uns beschäftigen wird. Denn wie gross auch der Unterschied zwischen Nord und Süd sein mag,—eine Sprache wurde von allen in verschiedenen Dialekten gesprochen, und eine Weltanschauung beherrschte ihr Denken.

Den ersten Einblick in die eigenartige Gedankenwelt der Buschmänner erhielt ich, als 1912 Professor Dr. Le Roux und Dr. de Villiers von der Universität Pretoria zu mir nach Gaub kamen, um sich in die Namasprache einführen zu lassen. Sie brachten einen erst kürzlich von Edison erfundenen Apparat zur Aufnahme menschlicher Sprachen mit. Es war die Absicht dieser Herren, Sprachproben von allen Sprachen Südwests aufzunehmen. Dazu bot sich reichlich Gelengenheit. Ich verfügte damals über Herero, Nama, Saan, Hottentotten resp. Nama, Bergdama und auch über eine Kolonie van !Kû-Buschmännern,

deren tuchtiger und zutunlicher Vormann *!Nani* war, 1,42 m gross. Diesen Vertretern aller südwester Völkerschaften wurde nun die Aufgabe gestellt, jeder solle in seiner Sprache eine ihm bekannte Fabel aus dem Fabelschatz seines Volkes in den Apparat erzählen und sich auf diesen Vortrag gut vorbereiten, damit Stockungen vermieden würden. Der Tag der Vorträge kam herbei. In meinen Studierzimmer wurde der geheimnisvolle Apparat aufgebaut. Eine grosse Kiste mit Wachsrollen fehlte nicht. Die Vorträge begannen. Des Staunens war kein Ende, wenn der Apparat nach vollendetem Vortrag die ganze Erzählung wortgetreu in menschlicher Stimme wiederholte, ohne sich auch nur ein einziges mal auf einem Fehler ertappen zu lassen. Nachdem alle genügend erzählt hatten, sollte der Buschmann !Nani noch einige Sätze seiner Sprache mit charakteristischen Schnalzlauten in den Apparat sagen, und dann sollte die wohlgelungene Forscherarbeit eingestellt werden. Buschmann !Nani aber hatte längst gemerkt, was die Herero und Ovambo und Bergdama trieben. Er wollte nicht hinter ihnen zurückstehen. Sätze ohne besonderen Sinn in den Apparat zu sprechen ging ihm gegen seinen Buschmannstolz, wo er doch überzeugt war, viel besseres leistern zu können. Auch er erzählte Buschmannfabeln, und zwar so, dass man hätte meinen können, er habe sich wochenlang auf diesen Vortrag vorbereitet. Der Professor war ganz glücklich. Er hatte nur eine Sorge, dass man den Buschmann etwa stören könnte. Es störte ihn aber niemand. Alle waren starr beim Anhören dieses Künstlers im Erzählen. Eine Rolle nach der andern wurde vollgesprochen, endlich, nach 55 Minuten, verliess den Vortragenden die Kraft. Mit Wasser mussten wir dem Erschöpften wieder aufhelfen. Aber seine Frau *Ti – !e*, 1,32 m gross, wollte nicht, dass die Erzählung ihres Mannes unvollendet bleibe. Ungerufen stellte sie sich vor den Apparat. Mit schneidender, hoher, klangreicher Stimme erzählte sie weiter, immer weiter,—nicht bis sie den Schluss ihres Wissens und Könnens erreicht hatte, sondern bis der Professor keine Aufnahmewalzen mehr hatte. An dem Tage ging mir ein Licht darüber auf, dass sogar der Buschmann eine Gedankenwelt hat, in der er lebt, und dass er eine Literatur besitzt, die sich sehen lassen kann. Ich wenigstens hätte aus Goethe oder Schiller nicht eine volle Stunde unvorbereitet vortragen mögen,—noch dazu vor einem Professor der Germanistik!

. . . .

Sie fragen: Was war es denn, was dieser Buschmann erzählte? Es waren bunt aneinander gereihte Erzählungen, aus dem Tier—und Pflanzenleben, Erzählungen von Sonne, Mond und Sternen, Erzählungen von Buschmännern und andern Menschen, von denen jede einzelne einen Pinselstrich bildete zu einem grossen und wunderlichen Gemälde, das wir " Weltanschauung der Buschmänner " nennen können.

Da gibt es, wie es scheint, keine Frage im Buschmannleben, die nicht in einer Erzählung eine Antwort findet. Besonders die

Frage " Warum?" und " Woher " wird in hundert Geschichten beantwortet. Es ist mir kein Volk bekannt, in dem diese beiden Fragen, die doch weltanschauliche Fragen sind, so vielfältig beantwortet werden, als im Volk der Kalahari-Buschmänner.

Der Buschmann is kein Wissenschaftler und er versteht es nicht, sich in Begriffen auszudrücken. Es scheint aber, dass er ein Dichter ist. Seine Fragen beantwortet er mit einer Dichtung. Man antwortet: Das tun manche andere Vòlker auch. Man sehe nur daraufhin die deutschen Märchen an! Gewiss! Aber es besteht doch ein Unterschied. An den deutschen Märchen ergötzt man sich. Man weiss aber, dass sie nicht wörtlich genommen werden dürfen. Der Buschmann aber glaubt an die Erzählungen, die ihm seine Alten mitgeteilt haben, und wenn er zu den alten Erzählungen Ergänzungen oder gar neue hinzufügt, so werden seine Zuhörer ihm Glauben schenken. Denn der Buschmann ist seiner Geistesverfassung nach noch ein Kind. Es scheint, dass der Wuchs seines Geistes etwa da die möglichste Grösse erreicht hat, wo unsere europäischen Kinder etwa im 6. oder 7. Lebensjahre stehen. Man muss aber mit diesem Urteil vorsichtig sein. Denn bei der Verfertigung seines Pfeiles hat er einen Scharfsinn an den Tag gelegt, den wir unter andern Völkern nicht finden, und was seine Lebensweise angeht, so ist wohl zu sagen, dass selbst ein hochgelehrter Professer sich im Buschmannfelde recht verlassen vorkommen würde, während der Buschmann mit grossem Scharfsinn die Mittel aufzuspüren vermag, die ihm das Leben fristen.

Alle Buschmannerzählungen sind zurückzuführen auf einige wenige weltanschauliche Ideen. Diese Ideen finden wir nirgends ausgesprochen. Der Buschmann ist eben nicht der Mann abstrakter Gedankengänge. Aber wir vermögen diese Leitideen aus den Erzählungen herauszuschälen. Unbewusst hat auch der Buschmann sie. Er kann sie nur nicht aussprechen. Aber sie sind für ihn gleichsam der Faden, auf den er seine vielen Erzählungen aufreiht.

Diese Erzählungen mögen verschieden von einander sein. Jeder Erzähler hat seine Variationen. Es mögen im Norden Erzählungen vorhanden sein. die im Süden unbekannt sind, und im Süden mag jedes Kind bestimmte Erzählungen kennen, von denen man im Norden nichts weiss. Aber die Grundideen sind im Norden und im Süden eins. Die Grundlinien der Weltanschauung sind überall dieselben, wenigstens soweit es mir möglich war, bei Buschmännern in die Lehre zu gehen.

Lassen Sie mich nun die einzelnen Leitideen anführen, indem ich mit kurzen Worten hinzufüge, wie sich diese Ideen im Buschmanngemüt in konkrete Vorstellungen verwandeln.

Die 1. Idee.

Die sichtbare Welt ist umgeben und durchdrungen von einer magischen Welt. Der Hintergrund der Welt der Erscheinungen ist daher nicht leer und tot, sondern im höchsten Grade lebendig.

Aus diesem magisch-lebendigen Hintergrund der Welt treten Lebensträger hervor. Erster Lebensträger ist der Buschmann. Neben, nicht unter ihm stehen als Lebensträger gleichberechtigt die Quellen und Flüsse, Wolken und Nebel, Berge und Flächen, Pflanzen und Tiere, Sonne und Gestirne.

Das Urgeschlecht der Buschmänner stand dieser magischen Welt besonders nahe. Daher verfügte es über grossartige magische Kräfte. Es hatte die Fähigkeit, sich nach Belieben in Tiergestalten und Bäume, Gewässer und Winde zu verwandeln.

Dann trat eine Zeit ein, in denen die Kraft der Verwandlungen verschwand. Die Formen erstarrten. Aus dieser Zeit stammen die Verschiedenheiten der Erscheinungswelt. Aber alles Sichtbare in der Natur gehört zur alten Buschmannverwandtschaft. Die Tiere der Gegenwart sind Buschmänner des Urgeschlechts. Der Mensch stammt nicht vom Affen ab, sondern der Affe ist ein Mensch, der nur nicht als solcher mehr erscheint, weil die Zeit der willkürlichen Verwandlungen dahin ist. Auch die Berge und Flächen, die Quellen und Ströme, die Jagdtiere und Vögel entstammen dem Urgeschlecht der Buschmänner. Sie leben. Sie können nützen und schaden. Man hat sie als Seinesgleichen anzusehen mit dem dumpfen Nebengefühl, dass in ihnen plötzlich etwas Ueberlegenes offenbar werden kann. Daher ist eine Anrede an all diese Dinge keineswegs sinnlos. Sie dient dazu, ein gutes Verhältnis zwischen dem Buschmann und den Dingen der Erscheinungswelt herzustellen. Man kann dadurch das Schädliche verhüten und das Nützliche fördern.

Dieser Grundidee hat der Buschmann in Hunderten von Erzählungen konkrete Einkleidung verliehen. Diese Erzählungen erheitern die Gemüter, klären dunkle Erscheinungen auf, vermitteln ein angenehmes Gruseln, und führen dem Buschmanngeist primitive Nahrung zu, denn andere Nahrung für seinen Geist kennt er nicht. Die Eltern und die ganz Alten sind es, die die Kunst des Erzählens üben. Aber System ist nicht in dem Unterricht. Je wie die Tagesereignisse sind, so ist die Auswahl der Geschichten, die am Abendfeuer erzählt werden. Daher kommt es, dass der Accent keineswegs bei allen gleich ist. Es kann in einer Sippe eine Erzählung besonders beliebt sein, die in einer andern nahezu unbekannt is. Der Forscher hat sich dann zu hüten, dass er nicht den Eindruck, den er bei einer Sippe gewinnt, verallgemeinert.

Es sei gestattet, die Erzählungen, die sich an die erste Idee anschliessen, mit wenigen Sätzen zu skizzieren. Die Urbuschmänner werden bei einigen Erzählern als zu einem grossen Familienverbande gehörig betrachtet. Mit jedem Familienglied geschieht dann Ueberraschendes und Wunderbares. Andere Erzähler berichten dieselben Geschichten als Einzeldarstellungen. Wo die Geschichten auf den Faden des Familienverbandes aufgereiht werden, gibt es selbstverständlich ein Familienoberhaupt, eine Hauptfrau, Söhne und Töchter, Schwiegersöhne und Schwiegertöchter. Der Alte gerät in mancherlei Verlegenheiten,

aus denen er sich aber immer wieder glücklich befreit durch seine magische Kraft. Der Sohn, hurtig und geschickt, wie ein Buschmannjäger sein muss, wird zum Wirbelwind, der irgendwo in den Bergen haust und von dort heute noch hervorbricht. Die faule Tochter, die vermöge ihrer magischen Kraft sich die Veldkost fast in den Mund waschen lasse, schläft schliesslich ganz ein, und wir sehen sie heute noch als Berg in der Fläche liegen. Ein Enkel wird zu einer Schlange, die in den Quellen hervorbricht, in den Flüssen sichtbar wird und dem Buschmann von heute äusserst wertvoll ist. Was sollte er ohne Wasser anfangen?

Die strenge Bindung an das Familienschema beeinträchtigt jedoch die Freiheit des Erzählers. Man weicht daher gern dieser Bindung aus und lässt die Urbuschmänner als Einzelwesen erscheinen. Ist nicht der Zauberer, den man kennt, auch so ein Einzelgänger? Waren nicht die Männer der Urzeit insgesamt gewaltige Zauberer? Da tritt dann der Feuermann, der *D'a' – + ao* auf, der aus der Ferne kommt und sich vor allen andern dadurch auszeichnet, dass sein Kopf feurig ist und Licht verbreitet, während alle andern im Zwielicht des Urdunkels nur mühsam das Wild erjagen und die Veldkost suchen können. Wenn aber der Feuermann bei ihnen ist, ist es taghell und der Jagdertrag erstaunlich gross. Leider hat Feuermann, dessen Lichtquelle nicht bei allen Erzählern sich im Kopf befindet, sondern auch etwa unter der Achselhöhle des rechten Armes ist, einen schlimmen Fehler an sich. Er beansprucht für sich die besten Fleischstücke. Darüber erzürnt wird im Männerrat beschlossen, dass man Feuermann töten will, um ihm nicht mehr die vorzüglichsten Fleischstücke zugestehen zu müssen; dass man aber die Lichtquelle erhalten möchte, um besser der Nahrungssuche nachgehen zu können. Man tötet ihn mit Pfeilschüssen, schneidet seinen Kopf ab, wirft ihn an den Himmel und hat nun, was man haben möchte: eine Sonne, die den Buschmanntag erleuchtet.

Aber der Mond fehlt noch und die Sterne auch. Sie werden auf die einfachste Weise erschaffen. Ein Urbuschmann nimmt seinen halbkreisförmig gebogenen Buschmannschuh, die Sandale, die vorn und hinten spitz und aufwärts gebogen ist, um zu verhindern, dass sich zwischen Fussohle und Sandale zuviel Steinchen sammeln und wirft ihn an den nächtlichen Himmel. Die Mondsichel entsteht daraus.

Der andere Schuh verbrennt am Feuer. Der erzürnte Besitzer wirft die Asche und feurigen Kohlen himmelan. Dort werden aus den Kohlen die Sterne, und aus der glühenden Asche wird die Milchstrasse.

Dass es nunmehr nachts nicht stockfinster ist, sondern ein Lichtschimmer auf der Erde ruht, ist gewiss angenehm für den, der in der Nacht draussen sein muss. Es hat dat aber die üble Folge, dass nun auch die bösen Menschen und die wilden Tiere in der Nacht ihr Unwesen treiben können.

Es liess sich kaum vermeiden, dass das Familienhaupt der Urbuschmänner mit der Zeit einen bestimmten Namen erhielt und ihm besondere Achtung entgegengebracht wurde.

So haben die Südbuschmänner ihren |*Kaggen* erhalten, der sich zwar in alle möglichen Tiere verwandeln kann,—denn er lebt heute noch,—sich aber mit Vorliebe in der Gestalt der Mantis zeigt. Dr. Bleek und seine Tochter Frl. Dora Bleek haben mit vorbildlichem Fleiss und wissenschaftlicher Genauigkeit ein grosses Material von Mantiserzählungen zusammengebracht. In zwei umfangreichen Werken kann man diese Erzählungen nachlesen. Man könnte fast auf den Gedanken kommen, den Buschmännern sei ein Gotteswesen bekannt, das sich in der Mantis offenbare. Es ist dann allerdings ein Gott nach Buschmannart. Er ist ein erstaunlich grosser Magier, der aber nicht nach Weisheit planmässig schafft, sondern nach Willkür allerlei wunderliche Stückchen liefert. Daneben ist er oft selbst in Verlegenheit, muss sich von andern helfen lassen, lügt sich heraus, wenn er mit der Wahrheit nicht weiterkommt, täuscht und betrügt ohne Bedenken, und wenn man ihn seiner magischen Gewalt entkleiden würde, käme ein richtiggehender Buschmann heraus.

Die Nordbuschmänner wissen gar wenig von der Mantis. Für sie ist *Huee* das Wesen, das auf der Grenze steht, aus einem grossen Urbuschmann ein Buschmanngott zu werden. Auch von ihm erzählt man wunderliche Geschichten. Er macht Menschen und tötet sie wieder. Sein Sohn macht ebenfalls Menschen, und zwar Buschmänner. Der Alte will das nicht haben. Er verwandelt sich in einen Affen aus Furcht. Der Sohn beruhight ihn aber und versichert ihm, dass die Buschmänner ihm nicht schaden werden. Da verwandelt er sich in einen Palmbaum, in einen Springbock, in ein Eland, endlich stirbt er und die Leute begraben ihn. Er kommt aber wieder aus dem Grabe hervor. Eine solche Gestalt wie |*Kaggen* und *Huee* reizen förmlich die Phantasie zu neuen Dichtungen. Es bedürfte wahrscheinlich nur eines besonders begabten Dichters, um in diesen beiden Heldengestalten die Buschmänner Götter sehen zu lassen. Ich selbst habe in früheren Jahren unter dem Eindruck gestanden, die Nordbuschmänner kennten ein göttliches Wesen und nennten es *Huee*. Dann aber erfuhr ich, dass man sich erzählt, *Huee* sei garkein richtiger Angehöriger des Urgeschlechts gewesen. Nur sein Sohn habe Buschmänner gebildet. *Huees* Vater aber sei aus unbekanntem, fernem Land gekommen, habe *Huee* zum Buschmannlande gebracht und sei dann wieder verschwunden.

Woher mögen nun die beiden Erscheinungen von |*Kaggen* und *Huee* stammen? Sind sie echtes Buschmanngut? Handelt es sich um ureigene Vorstellungen oder um Entlehnungen? Ich wage die Frage nicht zu entscheiden, möchte aber darauf hinweisen, dass sich im Sagenschatz der Hottentotten, Nama, Saan

und Bergdama Gegenstucke vorfinden. Dort begegnen wir dem ||*Gamab*-Glauben und den *Heiseb*-Erzählungen.

||*Gamab* is die Mantis, die sich in der Regenzeit zeigt, eine kleine Heuschrecke mit klugem Köpfchen und wenig scheuem Benehmen, die mit ihren Vorderarmen Motten fängt, sie mit dem Ellenbogen der Vorderarme festhält und seelenruhig verzehrt, auch wenn in der Entfernung eines halben Meters mehrere menschliche Augen diesen Vorgang interessiert beobachten.

Die alten Hottentotten nannten die Mantis nicht ||*Gamab* sindern ||*Gâuab*. Nun nennen sie aber das böse Urwesen auch ||*Gaûab* = Teufel. Mantis und Teufel tragen denselben Namen. Warum dies geschieht, kann niemand mehr sagen. Wir müssen daher fragen, was denn der Name bedeuten mag, um so einige Aufklärung zu bekommen. Da stellt es sich heraus, dass ||*Gam-a-b* der " Wasser-artige " bedeutet, und ||*Gâuab* kommt her von dem zusammengezogenen Satzteil ||*Gama-u-hâ-b* = der das Wasser besitzende. Demnach muss es wohl so sein, dass die alten Hottentotten, Nama und Saan ein göttliches Wesen kannten und annahmen, dass dieses im Besitz des Wassers sei und die Regenzeiten schaffe. Das ist durchaus begreiflich in einem Lande, wo der Nomade mehr als ein anderer abhängig vom Eintreten einer guten Regenzeit ist. Weil aber gerade in der Regenzeit plotzlich die Mantis mit ihrem klugen Benehmen auftaucht, das so ganz anders ist, als das Benehmen anderer Tiere, mag man sich veranlasst gesehen haben, diesem Tierchen den schon bereits vorhandenen Namen des Regengottes beizulegen und es als seine Verkörperung anzusehen.

Nach dem Erscheinen westländischer Kultur und Religion in Südafrika ist dann aus dem Regengott ||*Gamab* der Teufel ||*Gamab* oder ||*Gâuab* geworden.

Man sage nicht, der alte Hottentottengott sei *Tsui* – ||*goab* = Wundknie. *Tsui* = ||*goab* ist ein alter Volksheld, der den Volksfeind ‡*Ga* – ‡*gorib* in den Abgrund stiess und sich dabei das Knie verletzte. Ihn kennt man auch in vielen andern afrikanischen Stämmen.

Noch weniger sage man, dass *Heiseb* der alte Hottentottengott sei. *Heiseb* ist mehr der Eulenspiegel der Nama, Saan und Bergdama als ein Gott.

Merkwürdig aber ist, dass die Buschmänner von Stamm der !Kû in ihrem *Huee* ganz genau denselben ehren, den die Saan und Nama als *Heiseb* verehren. Alle Buschmannmalereien werden als das Werk von *Heiseb*, resp. von *Huee* angesehen. In allen rätselhaften Steinhaufen, auf die man vorsichtshalber als Gruss einen Stein wirft, ist einst *Heiseb* begraben worden und dann wieder auferstanden. Die !Kû-Buschmänner aber sagen dasselbe von *Huee*; auch er pflegte aus purer Schauspielerei zu sterben, sich begraben zu lassen und dann wieder von den Toten zu erstehen.

Bei der Frage nach der Weltanschauung der Buschmänner finden wir kein neues Material in den sehr zahlreichen Erzählungen von den Taten der Mantis und den Werken *Huees*. Diese beiden Gestalten mögen im Mittelpunkt dessen stehen, was die Erzähler zur Belustigung ihrer Zuhörer vortragen. Sie stehen aber keineswegs im Mittelpunkt der Weltanschauung. Ich wende mich daher zur.

2. Idee, von der her die Buschmannweltanschauung stark beeinflusst wird. Sie ist folgende:

Die in Tiere oder Erd- und Himmelskörper verwandelten Urmenschen haben ihre magischen Kräfte keineswegs eingebüsst, als sie ihre Dauerformen annahmen. Sie gebrauchen dieselben noch heute zum Heil oder Unheil des Buschmannes. An ihnen ist es, sich durch Vermeidung alles Ungehörigen ihrem Unwillen zu entziehen, und sie durch gelegentliche Anrufung günstig zu stimmen.

Die magischen Kräfte der Dinge und Tiere zeigen sich hauptsächlich im Vorherwissen zukünftiger Ereignisse.

Die Eule, die nachts umherfliegt, liest das künftige Geschehen aus der Helligkeit und Stellung der Gestirne und des Mondes. Steht man mit ihr auf freundschaftlichem Fuss, so kommt sie und berichtet durch lauten Schrei ihren Freunden, was ihnen bevorsteht. Dann können sie sich rechtzeitig gegen herannahende Gefahren schützen.

Der Specht, ein Tagvogel, erfährt die künftigen Dinge aus dem Spiegel stehender Gewässer. Auch er macht über das Gesehene seinen Freunden Mitteilung.

Die Schlange hat besondere Kenntnisse über die Vorgänge, die sich unterhalb der Erde abspielen. Wenn sie sich in der Nähe eines Grabes zeigt, so kann man sich über das Ergehen der Verstorbenen beruhigen. Es geht ihnen gut. Es werden daher nach einem Begräbnis Beobachtungsposten ausgestellt, die die Vorgänge am Grabe oder in der Nähe des Grabes erkunden müssen. Erblicken sie dort eine Schlange, so haben sie ihren Auftrag günstig erledigt. Sie melden das Gesehene der Familie des Toten. Dort begeben sich die Männer auf Jagd und die Weiber sammeln Feldkost in Menge, um mit dem Ertrag der Jagd und des Einsammelns ein frohes Totenmahl zu halten, das mit einem Tanz schliesst.

Ueberhaupt achtet man auf jedes auffällige und eigenartige Benehmen aller Tiere mit der prüfenden Frage, ob von dorther vielleicht eine Botschaft zu erwarten ist.

Besonders bedeutsam ist der eigene Körper, dessen einzelne Muskeln Empfangsapparate für magische Einwirkungen zur Zukunftsdeutung sind.

Zuckt der Rückenmuskel, so bedeutet das die baldige Erlegung eines Grosswildes, dessen Fleisch der Jäger auf dem Rücken heimtragen wird. Der Muskel fühlt diesen Druck bereits vorher.

Dasselbe ist der Fall, wenn die Wadenmuskeln zucken. Diese Muskeln fühlen im voraus das Abtröpfeln des Blutes vom erlegten und heimgetragenen Wild.

Wenn ein Gesichts- oder Rippenmuskel zuckt, so rührt das daher, dass eines Springbocks schwarze Streifen an diesen Körperteilen sich bemerkbar machen. Der Jager wird über den glücklichen Fang desselben froh werden.

Das Zucken der Augenmuskel deutet an, dass ein Verwandter in der Ferne sterben muss. Man wird um den Verlust weinen.

Es bedürfte eines eigenen Vortrages, wollte man in eine vollständige Besprechung alles dessen eintreten, was die Muskelzuckungen zu verkundigen haben.

Den Muskelzuckungen gleichwertig sind die Enthüllungen, die das Losorakel gibt. Fast jeder Buschmann besitzt ein solches. Es besteht entweder aus Knochen eines beliebten Wildes, oder aus der Haut eines Tieres, oder aus dem Holz eines mit magischer Kraft besonders stark erfullten Baumes. Zwei Knochen, zwei in Sandalenform geschnittene Fellchen, zwei Stäbchen genugen schon, um sich alle ungelösten Fragen losen zu lassen. Sie sind etwa fingerlang, eins muss aber etwas kleiner als das andere sein, denn der längere Teil ist männlich, der kürzere Teil aber weiblich. Ferner muss man die Oberseite von der Unterseite unterscheiden können. Besteht das Orakel aus zwei Fellstückchen, so lasst man die Haare darauf, um daran die Oberseite erkennen zu können. Auch ist es wichtig, dass man durch ein Zeichen den Kopf markiert.

Hat man nun eine Frage an das Orakel zu richten, will man etwa wissen, ob ein beabsichtigter Jagzug erfolgreich sein wird, so hockt man auf einer ebenen Fläche nieder, holt das Orakel aus dem kleinen Fellsäckchen, das jeder Buschmann unter dem linken Arm trägt, reinigt es; benetzt es mit Speichel, ermahnt es, die Wahrheit zu sagen, reibt es an der Stirn und wirft es dann etwa einen halben Meter hoch in die Luft. Wie die Losteile nun auch fallen mögen,—aus ihrer Lage zu einander und zum Loswerfer ist die Antwort abzulesen. Der Sicherheit halber richtet man eine Frage aber zu mehreren Malen an das Los. Lautet die Antwort verschieden, so nimmt man diejenige mit gutem Glauben an, die dem Fragenden am besten gefallt.

Es ist aber nicht nur das Orakel, mit dem man redet, es bittet oder ermahnt. Weil alle Dinge belebt sind, ist auch eine Anrede an alle Dinge möglich und sogar nutzlich. Von ihnen gehen ja magische Wirkungen aus, und diese Wirkungen können schädlich oder nutzlich sein. Daher ists geraten, in guten Beziehungen zu allem zu stehen. Wir sind geneigt, solche Anreden als Gebete aufzufassen und sagen dann wohl, der Buschmann bete die Sonne oder den Mond an. Dem ist aber nicht so. Die Anreden an Sonne und Mond haben denselben Sinn, den die Anrede an einen vorubergehenden Menschen hat, dem man

zeigen möchte, dass man mit ihm auf gutem Fuss zu stehen wünscht. Diese Anreden an hervorragende Naturerscheinungen, an Bäume, auch an Tiere sind daher keineswegs irgendwie geboten, oder werden zu bestimmten Zeiten vorgenommen. Es handelt sich dabei immer um ganz spontane Aeusserungen der Buschmannseele.

Geht die Sonne auf, so begrüsst man sie und sagt: O Sonne, du machst es wieder hell auf Erden. Zeige mir meinen Springbock. Ein anderer spricht: Wie rund bist du, o Sonne, und wie fröhlich. Du hast eben Nahrung in Fülle, ich aber bin mager vor Hunger. Die Sammlerin sagt: Zeige mir o Sonne, wo ich heute am meisten Feldzwiebelchen finden kann. Steht die Sonne heiss am Mittagshimmel, so blickt der Buschmann auf und seufzt: O Sonne, mach es nicht zu arg! Geht sie unter, so ruft er ihr nach: Auf Wiedersehen!

Auch den Mond redet man in gleicher Weise an. Zum Neumond spricht man: Da bist du wieder! Wir glaubten, du seiest tot, aber du lebst wieder. Lass auch uns leben, obwohl wir sterben müssen. Zum Vollmond spricht man: In wenig Tagen bist du fett und rund geworden, obwohl du so mager warst. Möchte es auch mir so ergehen! Beim Verschiessen einer Sternschnuppe denkt man abermals an den eigenen Hunger und sagt: Ihr da oben habt es gut. Ihr lebt in der Fülle. Wann werden wir es so gut haben?

Bei nächtlichem Gebrüll eines Löwen wird gesagt: Wie glücklich bist du, o Löwe! Du holst dir deine Nahrung in der Nacht und kannst am heissen Tage schlafen. Wer macht auch mich so glücklich?

Sieht man in der Ferne eine Giraffe vorbeischreiten, so verfehlt man nicht, ihr zuzurufen: Wann wirst Du, o Giraffe, unserm Pfeil erliegen? Wir möchten ein Orakel aus deiner Haut schneiden und dich damit hoch ehren!

Beim Anblick eines mit wilden Pflaumen beladenen Busches sagt die Sammlerin: Wie rundbäuchig seid ihr! Macht auch mich so. Gebt mir von eurem Ueberfluss. Nunmehr darf sie ungestraft von den Pflaumen nach Belieben pflücken.

Zerlegt man ein geschossenes Grosswild, so vergisst der Jäger nicht, ihm gut zuzureden und zu sagen: Sei nicht traurig darüber, dass ich dich getötet habe. Wir werden deine Gebeine sorgfältig wegpacken und nicht zerstreuen.

Selbst mit dem Grabstock, den die Sammlerin gebraucht, um Erdknollen zu graben, redet sie: Halte aus! Grabe aus! Rund wie du werde mein Leib! Scharf wie du sei immer mein Zahn!

Und der Jäger redet mit seinem Bogen: Jetzt spanne ich dich. Nun bist du gerundet. Das tue ich an dir, tue dasselbe an mir und gib mir heute Fleisch.

In diesem Zusammenhang muss auch ein Wort über den Buschmanntanz gesagt werden, denn er findet seine Deutung auf derselben Linie, auf der wir uns bei unsern Untersuchungen bewegen.

Der Tanz ist in den Augen der Buschmänner keineswegs nur ein Vergnügen. Gewiss, man mag ihn ansehen, als ein Ventil aufgespeicherter Kraft. Man mag ihn ansehen als ein Spiel erotischer Erregung. Sein eigentlicher tieferliegender Sinn ist das nicht.

Man tanzt, wenn der Neumond erscheint. Han tanzt, wenn Vollmond ist. Man tanzt, wenn man ein Grosswild erlegt hat. Man tanzt auch, wenn ein Europäer das wünscht, denn man erhofft von ihm ein Geschenk. Beim Tanz aber wird die Anrede, von der die Rede war, niemals fehlen, oder er ist nicht vollständig. Beim Tanz übt der Buschmann in versammelter Sippe genau dasselbe, was der Einzelne in seiner Anrede an Gestirne, Tiere und Dinge tat: die Sippe als solche setzt sich mit den Gestirnen, Tieren und Dingen in Verbindung, um sie günstig zu stimmen. Daher gibt es nahezu soviele Buschmanntänze, als es hervorragende Gestirne, Tiere und Dinge gibt. Als Wirkung des Tanzes erhofft man besondere Segnungen. Hier ist die Grenzscheide, wo aus der Anrede des Tanzes, die bereits zum Gesang geworden ist, das Gebet hervorgeht. Hier ist auch die Grenze, wo aus der Sippenversammlung bei geringer Förderung die kultische Gemeinderversammlung werden könnte und werden würde, wenn der Buschmann eine deutliche Gottesvorstellung hätte.

Als 3. Idee, aus der die Weltanschauung der Buschmänner hervorgegangen ist, kann ich daher nicht die Gottesidee nennen, sondern muss einen andern Gedankengang einschlagen. Dieser ist folgender:

Aus dem alten Geschlecht, in dem die Kräfte der magischen Welt ganz besonders wirksam waren, ragt als überlebender Rest der Zauberer in die Welt der Gegenwart hinein. Er hat heute noch die Fähigkeit, sich in jedes beliebige Tier verwandeln zu können. Seine Beziehungen zu allen Dingen sind so, dass er nahezu mit ihrer Hilfe allwissend und allgegenwärtig ist. Seine Kräfte reichen nahe an die Allmacht heran. Er kann den Menschen furchtbar schaden mit seinem fingerlangen Zauberpfeil. Er kann ihnen aber auch in allerlei Nöten wunderbar helfen durch sein Können.

Der Zauberer führt in der Regel ein einsames Leben. Er pflegt nicht bei seiner Sippe zu bleiben. Nur vorübergehend ist er daheim. Er besucht andere Sippen und wird von diesen während seines Besuches unterhalten. Das Beste vom Besten steht ihm zu. Dafür hat er die Leute darauf aufmerksam zu machen, wenn sich ein Unheil naht, oder wenn er in einem Menschen, der sich noch ganz gesund fühlt, bereits den Erreger einer schlimmen Krankheit sieht. Er muss dann diesen Krankheitskandidaten behandeln. Das geschieht in derselben Weise, in der er bei wirklich Kranken die Behandlung vornimmt. Die

Person muss sich legen. Der Zauberer sucht die Stelle, wo die Krankheit sitzt. Da befindet sich ein Krankheitserreger. Dieser kann aus einem lebendigen Tierchen bestehen, kann aber auch ein Dorn, ein Haar, ein Knochen, ein Nagel sein, den irgendwer unter den Lebenden oder Toten in den Körper hineingebracht hat. Hier setzt der Zauberer seine Lippen an und saugt. Nach vieler Mühe hat er endlich den Erreger im Munde. Manche Zauberer nehmen ihn dann aus dem Munde heraus, zeigen ihn den Leuten und werfen ihn ins Feuer. Andere stürzen davon, denn der Erreger ist in die Nasenhohle eingedrungen, und das Leben des Zauberers ist in Gefahr. Er muss draussen den Erreger aus der Nase herausziehen. Dabei fängt in der Regel die Nase an zu bluten. Der Zauberer kommt zurück, zeigt den Erreger, wirft ihn weg oder verbrennt ihn und reibt mit seinem Nasenblut die Stelle ein, wo der Gegenstand entfernt wurde, damit sich die Wunde ohne Narbe schliesst und die Krankheit nicht wiederkehrt.

Es kommen dabei rätselhafte, plötzliche Gesundungen vor. Als 1918 die Grippe im Anmarsch war, veranlasste ein Zauberer in Tsumeb alle Buschmänner, noch vor Ausbruch der Seuche den Ort zu verlassen. In einer Nacht waren sie verschwunden. Im weiten Buschmannvelde ereilte sie die Seuche nicht. Ein Europäer, der krank war, liess sich von einem Buschmannzauberer behandelin. Er schwor darauf, dass dieser Mann ihm eine Anzahl kleiner Skorpione aus dem Körper gesaugt habe, und dann sei es mit ihn besser geworden. Wenn schon ein geschulter Europäer solcher Suggestion erliegt, was will man da von einem Buschmann sagen? Der Zauberer wird aber nicht etwa wie ein Artzt um jedes Leibesübels willen in Anspruch genommen. Handelt es sich um eine Erkrankung, deren Ursache klar zutage liegt, so hilft man sich selbst. Ich kannte einen Buschmann, dessen erstes Glied vom Mittelfinger der linken Hand schwärte. Hätte er es mir gesagt, so hätte ich ihm gern und leicht durch eine kleine Operation helfen können. Er wusste aber nicht, dass man mit solchen Dingen zum Doktor gehen kann. Eines Tages brachte ihn sein Freund *!Nani* zu mir und bat für ihn um einen Lappen zum Verbinden. Der Mann hatte mit Hilfe eines rostigen alten Taschenmessers mit eigener Hand das Fingerglied im Gelenk ausgelöst. Er begriff weder meine Verwunderung noch mein Entsetzen. Einen Lappen zum Verbinden wollte er gern haben, mehr nicht. Er bekam ihn und der Finger war in kurzer Zeit heil.

Aus sich selbst heraus weiss allerdings ein Zauberer nicht arg viel. Es hilft ihm aber, dass er die Kunst der Verwandlung in Tierkörper versteht. Während dann sein eigener Körper nachts liegt und schläft, geht sein Geist über in eine Eule, in einen Schakal oder in ein anderes Tier, das mit grosser Geschwindigkeit des Fluges oder des Laufens begabt ist und zieht auf diese Weise über fern wohnende Personen Erkundigungen ein, um den fragenden Angehörigen Mitteilung machen su können.

Wehe aber, wenn man über einen Zauberer übel redet. Er

hört das, auch wenn er nicht anwesend ist. Ueber einen Zauberer unterhält man sich daher in einer Buschmanngesellschaft nur im Flüsterton. Wenn er jemand strafen oder schaden will, so ist ihm das ein Leichtes. Sein durchbohrender Blick tragt bereits durch die Augen hindurch in den Körper eine Krankheit. Daher ists nicht gut, einem Zauberer frech in die Augen zu sehen. Ausserdem hat er aber noch seinen Revolver, mit dem er Unheil anrichten kann.

Dieser sogenannte "Buschmannrevolver," den man fast in allen Völkermuseen sehen kann, besteht aus einem fingerlangen Miniaturbogen mit Sehne. Der Bogen ist aus gesplissenem Horn hergestellt. Dazu gehören etwa 20 fingerlange Pfeile, die aus zwei Teilen bestehen. Der Schaft ist aus hartem Gras, an beiden Seiten, oben und unten, mit einer dunnen Tiersehne sorgfaltig umwickelt. Die Pfeilspitze aber besteht aus Horn, das an einem Ende stumpf abgeschnitten, am andern Ende aber nadelscharf ist. Die nadelscharfe Spitze ist in das Mark des Pfeilschaftes versenkt. In den Museen findet man nun hin und her die Behauptung, die Pfeile seien vergiftet, und der Buschmann schiesse damit seinen schlafenden Feind und töte ihn durch das Gift. Das ist durchaus falsch. Es ist unmöglich, den Pfeil so zuzurichten, dass die scharfe Spitze umgesteckt und nach vorn gerichtet werden kann. Nein, bei dem Buschmannrevolver handelt es sich um eine magische Waffe. Wenn man einem Feind schaden will, nimmt man den Bogen und einen Pfeil dazu, so, wie er in dem fingerlangen Lederköcher steckt, und schiesst ihn mit starken Verwünschungen in die Gegend ab, in der der Feind wohnt. Dort verwandelt er sich im Körper des Verwüuschten in einen Krankheitserreger, den nur ganz starke andere Zauberer zu entfernen vermögen. Wer von einem solchen Pfeil angeschossen ist, muss sterben, das ist der feste Glaube der Buschmänner. Sie sagen, wenn der Tod auch nicht alsbald eintrete, so trete er doch bestimmt nach einigen Jahren ein.

Auch die Geister der Abgeschiedenen verfügen über einen solchen Buschmannerevolver. Durch dessen Pfeile werden die unheilbaren Krankheiten erzeugt, an denen der Mensch stirbt.

Fur seine Freunde fertigt der grosse Zauberer auch solche Revolver an. Man findet sie daher bei fast allen Männern im kleinen Fellsäckchen, in dem der Buschmann seine kleinen Geräte mit sich zu nehmen pflegt. Damit können sie sich gegen lebende Feinde schützen. Damit können sie sich aber auch, wenn sie einmal nachts allein im Freien schlafen müssen und vor Furcht vor bösen Geistern nicht schlafen können, vor Schaden schützen. Man schiesst dann unter starken Verwünschungen einige Pfeile in alle Windrichtungen und ist davon überzeugt, dass nunmehr um sie herum ein Bannkreis entstanden ist, in den die bösen Geister nicht einzudringen vermögen.

Ist also das Losorakel ein wertvoller Besitz, um die Rätsel des Buschmannlebens zu enträtseln, so ist der Buschmannrevolver sein Gegenstück. Er bewahrt vor augenblicklicher Gefahr.

Die Kraft des Orakels und Revolvers aber ist rein magisch. Die Bestandteile sind ja solchen Gegenständen oder Tieren entnommen, die voll von magischen Kräften sind.

. . . .

Ich gehe nunmehr zur Besprechung der 4. leitenden Idee der Weltanschauung eines Buschmanns über. Durch ein Versehen oder durch den Unglauben ist einst der Tod in die Welt gekommen. Gegen den Tod kann man sich eine Zeitlang durch Benutzung der Orakel und durch den Revolver schützen. Aber eines Tages muss man dennoch sterben. Der Tod bedeutet aber keineswegs einen Untergang und ein völliges Verschwinden. Tiere können wiedererstehen, wenn von ihrem Tierkörper noch ein Teil erhalten ist. Sie gehören ja zum Urgeschlecht. Aber Menschen erstehen nicht wieder. Nur der Geist lebt in der magischen Welt. Unter allen Geistern ist jedoch für die Sippe der Urvater am bedeutendsten. Ihn in Notzeiten und auch bei anderen Veranlassungen anzurufen gehört sich für einen Buschmann. An diesem Punkt setzt religiöses Empfinden ein, und die Ahnung eines Ueberwesens, das des Urvaters, dämmert auf. Der Buschmann fühlt sich nicht verlassen, sondern er weiss, dass der Urvater ein gütiges Auge auf seine Sippe richtet, wenn diese sich gläubig und vertrauensvoll an ihn wendet. Der sterbende Buschmann weiss, dass sein Geist zum Urvater geht. Dort wird er das Buschmannleben fortsetzen, nur mit dem Unterschied, dass dort das Jagdfeld von Wild aller Arten wimmelt, und das Sammelfeld überreich an nährender und schmackhafter Veldkost ist. Aber der Zauberer ist auch dort noch Zauberer, und sein Pfeil kann den Erdbewohnern schweren Schaden bringen. Der Jäger bleibt Jäger, und die Sammlerin bleibt Sammlerin.

Sehr verschieden sind die Erzählungen, die vom Ursprung des Todes handeln. Die einen sagen, er sei durch ein absichtliches oder unabsichtliches Versehen entstanden. Der Mond, der monatlich stirbt, und immer wieder auflebt, habe die Laus, alias Schildkröte, alias Kamäleon mit der Botschaft zu den Menschen geschickt, dass sie zwar sterben müssten wie er, dass sie aber immer wieder aufleben würden, wie auch der Neumond wieder auflebe. Eins dieser langsamen Tiere aber habe entweder die Botschaft vergessen, oder habe zu lange auf dem Wege verweilt, und so habe der schnellfüssige Hase, (auch ein Buschmann aus dem Urgeschlecht) die Botschaft falsch überbracht mit dem Wortlaut: Wie der Mond stirbt, so sollt auch ihr sterben und immerdar tot bleiben. Als der Mond dahinter kam, zerschlug er des Hasen Lügenmaul, dass nun bis heute die Hasenscharte trägt. Das Unglück war aber geschehen, und konnte nicht mehr gutgemacht werden.

Andere sagen, ein Jüngling weinte über den zu erwartenden Tod seiner Mutter. Der Mond tröstete ihn und sagte: Wie ich sterbe, so wird auch sie sterben, und wie ich wieder auflebe, so wird sie wieder leben. Der junge M nn glaubte dem Mond nicht.

Zur Strafe für seinen Unglauben starb die Mutter, und alle Menschen müssen seitdem gleichfalls sterben.

Die Variation dieser Sage hat sich dermassen vielfältig unter den Stämmen Afrikas gestaltet, das es ein Buch füllen würde, wenn man alle Variationen aufzählen und berichten wollte. Die Herero nennen offenbar aus diesem Grunde den Hasen *ombi*= der Böse. und essen sein Fleisch nicht. Es unterliegt aber kaum einem Zweifel, dass diese Sage aus den Erzählungen der Buschmänner hervorgegangen ist.

Dass ein Tierkörper wenn er dem Tode verfallen ist, wieder erstehen kann, falls nur noch ein kleiner Teil erhalten blieb, ist der Gegenstand vieler Erzählungen, die von den Hottentotten aufgenommen und weiter ausgeführt wurden. Auch das Urgeschlecht der Menschen erneuerte sich auf diese Weise. Als einst der Sohn des |*Kaggen* von Pavianen getötet würde, und sie dann mit dessen Auge ein Ballspiel veranstalteten, erhaschte |*Kaggen* das Auge, legte es in ein Gewässer, und der Sohn wurde aus dem Auge wieder vollständig hergestellt. Aber das Urgeschlecht ist dahin, und die Menschen der Gegenwart finden ihre letzte Ruhestätte im Grabe.

Da aber der Geist in die magische Welt eingeht, besteht der feste Glaube daran, dass der Altvater einer Sippe erreichbar ist, ganz besonders an dessen Grabe, wenn man es weiss, aber auch überall sonstwo, wo man sich eben befindet. Von ihm hat man einst die Kunst gelernt, mit zwei Hölzern ein Feuer anzuquirlen. In den Segnungen eines solchen Feuers ist der Segen des Altvaters spürbar. Daher lässt man das ganze Jahr das Feuer des Werftältesten nicht ausgehen. Am Neujahrstage aber, wenn die neue Zwiebelernte begonnen werden soll, facht der Werftälteste ein neues Feuer an. Dieses Neujahrsfest wird gefeiert, sobald die Regenzeit vorbei ist, und die wilden Veldzwiebelchen reif sind. Dann kündigt etwa Anfang April der Werftälteste am Vorabend an, dass morgen das neue Jahr beginne. Er lässt das Feuer des alten Jahres in der Nacht ersterben. Vor Sonnenaufgang versammeln sich dann Männer und Frauen, Greise und Kinder im Halbkreis um ihn und hocken auf den Boden nieder. Er selbst sitzt in der Mitte des Kreises, hat das Feuerholz under seinen Füssen liegen, und das Quirlholz umfasst er mit beiden Händen, setzt es in die Vertiefung des Feuerholzes und quirlt nun, indem er nicht zu einem verstorbenen Vater oder Grossvater, sondern zu dem Altvater der Sippe betet:

Mba, nati |*je a a,*
nati |*khoma a,*
|*nâ a* |*â mi 'm,*
dsisn hoese |*na na* |*koaa,*

d. h. "Vater, ich komme zu dir,
ich flehe dich an,
gib mir Nahrung
und allerlei Dinge,
von denen ich leben kann."

Fällt dann der Funke, ist daran ein winziges Flämmchen im zarten Gras durch leisen Hauch geweckt, ist durch Hinzufügung von immer dickeren trocknen Holzstückchen ein Feuer entstanden, dann gehen die Männer ins Jagdfeld und die Frauen und Mädchen gehen ins Sammelfeld, um die ersten Zwiebelchen des neuen Jahres einzusammeln. Niemand geniesst von dem Ernteertrag. Er wird zu den Füssen des Alten am Feuer niedergelegt. Dieser röstet sie und bringt einen kleinen Teil davon zu einem ihm bekannten nahen Ahnengrabe, wo er sie mit den Worten niedersetzt: Vater, iss, dass deine Kinder auch essen können. Wenn er heimgekehrt ist, wird der Tagesertrag an Fleisch und Zweibeln von allen verzehrt. Ein Frevel und eine Sünde aber wäre es, vor dieser Feier schon davon zu geniessen. Ein Buschmann erzähalte mir, dass er einen Mann kenne, der im Zorn seine Frau erschlagen habe, weil sie vorzeitig Zwiebeln gegessen habe, denn das erzürne den Altvater, und er entziehe dann der ganzen Sippe seinen Segen.

. . . .

Damit haben wir das Gebiet der Buschmannweltanschauung betreten, in dem die Rede davon sein muss, welchen Einfluss nun diese eigenartige Weltanschauung auf des praktische Verhalten des Buschmannes ausübe, kurz gesagt: wir müssen noch ein Wort über die Buschmannethik sagen.

Sittenlehren können verschieden normiert sein. Die christliche Ethik lehrt uns: Tue das Gute und meide das Böse. Manche Künstlerethik baut sich auf dem Satz auf: Gut ist, was gefällt, schlecht ist, was nicht gefällt. Man stellt da das Schöne und Hässliche einander gegenüber. Der leitende Grundsatz der Buschmänner ist: Was nützlich ist, das ist geboten, was schädlich ist, ist zu vermeiden. Hier sind also die beiden Pole Nützlich und Schädlich richtungangebend. So lebten es die Alten des Urgeschlechtes vor. So wird es gelehrt in allen Erzählungen, die nicht lediglich der Aufheiterung dienen, und die Brauchbarkeit dieser Maxime erprobt man im ganzen Buschmannleben.

Aus diesem Satz ergeben sich auf Grund der magischen Weltanschauung die verschiedenen Gebote, die das Buschmannleben regulieren. Der Kürze wegen seien sie nicht umschrieben, sondern kurz formuliert mit dem Bemerken, dass sich noch viele andere hinzufügen liessen.

1. Du sollst die Knochen eines geschätzten Wildes nicht achtelos umherliegen lassen, sondern an einem Ort aufhäufen, damit der Springbock dich nicht im Jagdvelde meide.

2. Du sollst gewisse Fleischteile der Tiere nicht essen, denn es sind diejenigen Teile, die noch Menschenfleisch des Urgeschlechtes darstellen, das sich in Tiere verwandelte.

3. Wenn du im Mondschein ein Wild erlegst, so hüte dich sorgfältig, dass du den Mond nicht ansiehst, denn er vermerkt

es übel, dass du ihm ein Tier erschossen hast, und durch dein Auge könnte dir Uebelkeit und Krankheit vom Mond aus in den Leib fahren.

4. Auf ein Grab, auf den Regenbogen, auf den Mond sollst du nicht mit ausgestrecktem Zeigefinger hinweisen, denn sie sind Menschen des Urgeschlechts und wollen mit Respekt behandelt werden.

5. Das Wasser einer Quelle sollst du nicht verunreinigen, damit du die Wasserschlange nicht erzürnst und sie dich nicht strafe.

6. Du sollst nicht murren, wenn dir auf deiner Jagd ein mageres Wild beschert wurde. An einem andern Tage wird dir dann ein fettes Wild zuteil werden. Murrst du aber, so bekommst du uberhaupt nichts mehr und dein Jagdglück is dahin.

7. Beobachte den Wirbelwind und den Sturm, sowie das Gewitter mit Ehrerbietung. Während sie vorüberziehen, lass deine Beschäftigung ruhen und verbiete auch deinen Kindern das Spielen.

8. Den Blitz magst du scharf ins Auge fassen, denn wenn er sich in deinem Auge wiederspiegelt und sieht, dass du dich fürchtest, so schadet er dir nicht. Hüte dich aber vor einem frechen Blick.

9. Gehe nicht ohne triftigen Grund an einem Grabe vorbei, denn sonst störst du die Ruhe eines Toten. Musst du aber vorbeigehen, so grüsse den Toten und wirf ihm einen Stein auf sein Grab

10. Gestatte deinem Kinde nicht, mit kleinen Tieren zu spielen. Töte die kleinen Tiere, damit sie nicht gequält werden. Wenn deine Kinder sie quälen, so wird ihr Verstand so gering bleiben, wie der der kleinen Tiere.

11. Pilze sind die Kinder des Regens. Tritt nicht auf sie, damit sich der Regen nicht verziehe.

12. Lass dein Kind nie das Herz eines Schakals essen, sonst wird es furchtsam, wie er.

13. Ein Jager esse mit Vorliebe vom Fleisch langsamgehender Tiere, damit ihm das Jagwild nicht davonrennt, sondern fein bedachtig geht.

14. Bleibe in deiner Hutte, wenn draussen eine Eule schreit. Wurdest du sie durch deine Bewegungen verscheuchen, so müsstest du es büssen, denn sie gehört zum Urgeschlecht der Buschmanner und ist ein vielvermögender Zauberer.

15. Gib deinen Kindern die rohe Lunge des Strausses zu essen, dann werden sie eine gute Lunge bekommen, die kräftig zu reden vermag.

16. Gib deinem Kinde das Herz eines Leoparden zu essen, damit es furchtlos werde, wie er.

17. Verschütte kein Wasser unachtsam, damit die Quelle nicht versiege.

18. Töte kein Tier in der Nähe eines Grabes. Der Tote könnte es dir als Frevel anrechnen und dich strafen, denn die Gräber sind Freistätten für das Jagdwild.

19. Wirf den unteren Mühlstein nicht achtlos auf den Boden, wenn du ihn aufgehoben hast. Du könntest sonst mit Mangel an harter Veldkost gestraft werden, die man auf dem Mahlstein zermalen muss.

20. Fragt dich jemand, wo dein Vater begraben sei, dann zeige die Richtung mit deinen gewölbten Lippen an, aber nicht mit der Hand, damit du deinen Vater nicht im Grabe beunruhigst, etc.

. . . .

Aus dem Grundsatz der Buschmannethik: Was nützlich ist, ist erlaubt, was schädlich ist, muss vermieden oder bekämpft werden, ergeben sich auch die Verhaltungsmassregeln andern Buschmannsippen und vor allem den Europäern gegenüber.

Jede Buschmannsippe besitzt ein von den Vatern ererbtes Sippengebiet. Manche Sippen besitzen sogar deren zwei,—ein Sommerveld und ein Winterveld. Diese Gebiete haben ganz bestimmte Grenzen. Der Buschmann nun, der in einem fremden Sippengebiet der Jagd obliegt oder Feldkost sucht, kann sicher sein, dass ihn eines Tages ein vergifteter Pfeil treffen wird, denn er ist ein Schädling. Schädlinge bringt man um. Man ist dem Buschmann an die Lebensader gegangen. Wie soll er ohne Veldkost und Jagdwild leben können?

Ist aber ein Sippenmitglied umgebracht, so setzt sofort die Blutrache ein. Daher kommt es, dass es kaum zwei benachbarte Buschmannsippen gibt, die nicht in bitterster Feindschaft leben, weil ein blutiger Akt der Blutrache stets einen andern nach sich zieht und kaum zum Erlöschen kommt.

Kauft ein Farmer eine Farm von der Regierung, und wohnt eine Buschmannsippe auf dieser bisher unbebauten Farm, so liegt es in der Regel an dem Verhalten des Farmers, wie sich seine Zukunft gestalten soll. Der Farmer ist dem Buschmann an sich nicht verhasst. Man kann unter Umständen von ihm viel erhalten, was man sich sonst versagen müsste, z. B. Tabak und Streichhölzer. Zudem will der Farmer nur einen kleinen Bauplatz bebauen. Der Verlust eines Stückchen Landes bekümmert den Buschmann nicht, zumal sein Gebiet ja so sehr gross ist. Auch dass der Farmer einen Garten anlegt, Bäume pflanzt und dergleichen tut, ist kein Grund zur Feindschaft. Selbst dass er Viehzucht betreibt macht nicht viel aus. Der Buschmann hat keine Verwendung für das Gras, und das Wild des Veldes wird schon genug haben.

Aber drei Dinge sind es, die die Wut und Rache des Buschmannes hervorrufen. Man darf ihm das Wasser nicht verbieten,

auch nicht die Jagd und auch nicht die Veldkost. Wer das tut, erklärt ihm den Krieg, und die Kriegserklärung wird angenommen. Die Geschichte mancher Farm ist des Zeuge.

Es gibt zahlreiche Farmer, die keine anderen Farmarbeiter haben wollen, als die junge Mannschaft einer auf der Farm eingesessenen Buschmannsippe. Da wird kaum gestohlen, und die Arbeiter laufen nicht davon. Die Alten freuen sich, dass die Jungen Tabak und Streichhölzer und andere Dinge mitbringen. Sie selbst leben ihr altes Buschmannleben ungestört weiter.

Andere Farmer aber dürfen sich kaum hinauswagen, ohne einen Giftpfeil fürchten zu müssen, denn sie haben dem Buschmann in Unkenntnis der Verhältnisse den Krieg erklärt, indem sie dieselben entweder von der Farm verwiesen, oder ihnen eins der drei lebenswichtigen Dinge verboten.

Die Landesregierung sollte daher immer, wenn sie eine Farm im Buschmanngelände verkauft, im Kaufvertrag die Bestimmung aufnehmen, das seiner dort lebenden Buschmannsippe weder die Jagd, noch das Wasser, noch die Veldkost verboten werden dürfe. Die Bestimmung wurde ja nur für eine absehbar kurze Zeit Bedeutung haben. Ist das junge Geschlecht zur Arbeit erzogen, und sind die Alten hinweggestorben, so regeln sich die neuen Verhältnisse von selbst.

Besonders freudig aber ist es zu begrüssen, dass die Landesregierung beabsichtigt, im Norden ein Buschmannreservat für die Saan einzurichten, und im Osten eins für die Kalahari-Buschmänner. Kommende Geschlechter werden es der Regierung danken, dass sie dazu beigetragen hat, dass eins der interessantesten Völker des Erdballes durch weise Massnahmen der Regierung nicht dem drohenden Austerben anheimgefallen ist.

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RELATIONSHIP BETWEEN THE NATION AND ITS LANGUAGE

BY

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Read 6 July, 1937.

The legend of the Tower of Babel, when the Lord struck the disobedient and rebellious humanity so that they could not understand each other any more, has its conciliatory and reconciling counterpart in the pentecostal legend, when the Holy Spirit descended on the people of all nations so that they understood each other without the help of interpretation. Well-willingness and altruistic inclination, the eternal but never materialised hope for an everlasting world peace find their expression in the fiery tongues and the white dove of the biblical legend of yore. Whereas the Hebrew word "Babel" stands for "confusion," the humanity of our age is torn between Babel and Pentecost. Hence the question: What does the nation mean to the language? And the other one: What is the language to the nation? Through all the ages these questions have been asked, and man will keep on asking them.

The answers have never been the same. There is no answer which can or may claim finality, for these questions and the answers to them are vitally linked up with the ever-changing outlook on life and the interpretation of the meaning of individualism and nationalism.

No scientists have ever been able to solve the enigma of the bond existing between a nation and its language as they all look at it from a different angle, which is always individualistic, and no less so if the scientists happen to be champions of nationalism.

A national linguist will have his answer ready, a man of democratic ideas his, and a man of the city will solve the problem in a way different from a man living in agricultural surroundings. Differentiate they will all. To quote Dr. Vossler, the author of *Frankreichs Kultur in Spiegel seiner Sprache*, there are three kinds of linguists: The sceptical, the dogmatical, the critical.

If dogmatical stands for political, then the critical is certainly the one who should be recognised universally as the most impartial one.

Let us try and forget the political passions and the national "demands" of our times which rock the world of our age, let us try also to escape the narrow confines of personal individualism.

If we can do that then we must come to the conclusion that nation and language are not necessarily one. We even must come to the conviction that the language we learnt to speak in our childhood need not necessarily be the language of our parents. Thus the term "mother language" is idealistic and theoretical only. There is no such thing as a mother tongue. Supposing a child born of German parents loses its parents in its early infancy and is brought up by English foster-parents, the child's mother tongue then will certainly be English and not German. Features of character may be inherited by a child but not necessarily a language. The knowledge of a language must be acquired by every individual child. Moreover, it is a pious superstition to believe that a child born of German parents and brought up by English foster-parents will find it easier to acquire the knowledge of the German language than children born of English parents and also growing up in an English surrounding. There are no statistics to prove that superstition to be a fact.

The conclusion that a nation and its language are not inseparable may be deduced from the fact that hardly one nation, if any, is entirely and unreservedly responsible for the creation of its language. It is obvious that this must be so, because there is nothing more uncertain or fluctuating than the boundaries of a nation, not only the geographical but also the spiritual ones.

If you take away all that has been borrowed by a so-called national language from others in the course of 1,500 years very little will remain.

A national language can be dissected by scientific analysis, and thus it will be shown that many branches of human knowledge are the property of the whole human race.

To mention only a few of many: the number "1" is much more than a number, and is the same originally whether we speak English, German, Russian, or any other language known to the average man. It means the "original being," the forefather of humanity, the Adam of the biblical Paradise, he who lives and breathes. It also means the original woman, she who lives and gives life. Starting from the old hypothetic root *qu* one easily finds a bridge to the Gothic form *quina* (female) and to *huomo* and the Latin *vivere* and *cibus*. The German "Wesen" and the Afrikaans *wees*, no less than the Latin *femina* and the English *queen*, as well as the Russian *ẓiná* and *ẓivo* and the Greek εἷς are all members of the same family. Old Sanscrit texts have the word *a/vah at*.

There is no need to go into philological details. Those interested in the history of languages may get the necessary information from any grammar of Indo-European languages.

A few words more about the number 100. No nation, not even a continent, can claim this number. It is neither Italo-Celtic nor Aryan, neither Irano-Persian nor Indian, Teutonic or Slavonic. It is the property of all and of none—it is original.

It has changed since it became part of the many languages dividing them by changing into two separate groups—the "*saten-*" and the "kentensprachen" as Kretzschmar puts it. Thus we have:

Skr.: *sata.*	Early Germ.: *kemto.*
Lith.: *szîmtas.*	Greek: *ἑκατὸν*
Old Slavonic: *sutó.*	Lat.: *centum.*
Russ.: *sto.*	Germ.: *hundert.*

Etc.

This *hundert* or *hundred* is a combination of hund *(kemt)* + *rathjan*, which is Gothic and stands for "to count," and reappears in English in the verb "to rate."

The interesting thing in this number is that neither *kent* nor *sata* means "a hundred" at all. Its original translation is rather "ten" (10) and, ethymologically speaking, it is closely related to the second syllable of the Latin words *viginti*, *triginta*, etc., so that *kent* and *sata*, etc., are ten times the unity of ten. This could be regarded as a further indication of the originality of the numbers going back to the times when the foremost means of counting were the fingers of the human hands.

What was said of the numbers 1 and 100 also applies, of course, to the remaining numbers.

Thus numbers cannot be called part of a national language, and a very important branch, without which no language can be complete, falls away. So does everything connected with numbers, i.e., measures and weights.

"Pound" and "Pfund" are Latin; the original word—original *cum grano salis*—is *pondó*, which should be in close relation with *pondus*, although Friedrich Kluge denies it without however giving reasons for his denial. It would be a matter of further investigation to find out why the Italian word *libra* has been taken over by English and not by German as a measure of weight, while in Italy it stands for a monetary unity. It is a matter of further investigation to prove whether the French Louis d'or owes its name to popular ethymology changing the original *livre d'or* into *Louis d'or.*

Even *shilling* with its Gothic brother *skilla* and the identical German word *Schelle* have their relations in Italy and France, where we find *scellino* and *escalin*, and there is even a *sklezi* in old Slavonic languages.

There is no need to mention that modern inventions and progress generally have created their own language as commonly international as progress itself, that medical science has its language as international as are illness and death. It is very likely that the struggle of the purists who in this time of resuscitated nationalism think the time for harvest has come is in vain. The results achieved by purism are sometimes bordering the ridiculous. Some German purist suggests that *Elektrizität* should be substituted by *glitz*. To "electrify" should become

verglitzen, and an electrically driven locomotive should be a *Glitzling*. A steam-driven locomotive should be a *Dampfling*. Locomotive generally is to be a *Ziehling*. Why, the good old trek ox then must be rechristened into *Ziehling* also, because it "moves" the wagon away from its "locum." What possibilities! An "officer" then should be "he who does his duty," and a "revolver" "something in which something turns round." ". . . and the killer pointed his fully charged 'something in which something turns round' to the breast of his trembling victim. . . ."

No linguist will find fault with the endeavour to oust foreign words for which there are good home-made and home-known ones. It is perfectly correct for an Afrikaans-speaking man to avoid *te arriveer* and to say *aankom* instead.

The language richest in synonyms—apart from Russian—is certainly English—richest because in the year 1066 William the Conqueror brought along the whole treasure of his Norman language, which was welded with the language of England's inhabitants into a means of conveying ideas as marvellously flexible and pliable as hardly any other. What national language could possibly remain in the British Islands if purists succeeded in purifying English thoroughly. Then we had to cut out *assassination* because of its French "origin," and the French would have to cut it out too, because it is not French at all, but Arabic; *hashshashin* is an action committed by someone encouraged to a rash action. But *murder* is not a Teutonic monopoly either; we find the root of this word somewhere in Mongolia, and the old Serbian language has the word *mrti̥*, which means "to die" and "to kill."

Fury is the Latin *furor*, but "wrath," Icelandish, *reithi*, is a poor substitute for fury because of its slightly different meaning.

There would be no British *admiral* left because *amiral* is Arabic with the definite article *al* at the end of *amir*, which means "ruling master." There would be no *tea*, because even the Russian *tsai* is Chinese. "To attain," from Lat. *attingere*, should be dropped, but "to reach" is not an equivalent. Instead of *people*, *folk* would have to be used. *Chief* being derived from *caput* and "street" from *stratum* should have no place in the English language.

There would be no excuse for "alms" as the Greek "ἐλεεμοσύνη" is its ancestor.

Lake Winder "mere" should have to go because "mere" is the old Indian *mrie*, which is reflected in the Latin *mare* (plr. *maria*), which latter, by the way, explains the French *la mer*, feminine by wrong analogy.

The witches in Shakespeare's "Macbeth" should not have greeted Macbeth with "Hail thee, Macbeth," for "hail" is not Teutonic, but has its origin in a word which in the old Prussian language is something like *kail-ustikan*, and means "healthy," just like the modern Russian *zẹlui*. The word goes back to a

hypothetic *kélę* of perhaps Sanskrit derivation. Isn't it strange that the typical German greeting "Heil," which could be expected to be of cleanly Teutonic ancestry, has been preserved in its proper meaning in Slavonic languages?

To churn has Slavonic parents too, for Lithuanian *gîrnos* and the old Bulgarian *zrnę* stand for "a hand-worked mill."

Although *to wield* is found in old English already as *waldian*, it is a fact that the first two syllables of *Wladiwostok* have the same meaning. The Russian *vladiti* and the Gothic *valdan*—the *former* a liquida metathesis of the latter—have a hypothetical Sanscrit root *vęlda*, the meaning of which is "to wield authority."

It is not going too far, when purifying a language, to cut out all the words of family life. Take one striking example, 'child," *kind*, and its Russian word *diéti*, the Latin word *gens*, the old Bulgarian *tshêdi*, the Greek γίγνομαι, the Sanscrit *jan*, all of them go back to the Indo-European root *qu̯* mentioned already in connection with the number "one." By the way, the German verb *zeugen*, "to beget," has kept its meaning purer than the development of this Indo-European root shows in other languages.

There is no difficulty in showing that many words looked upon as very English ones by the man in the street are of foreign origin.

To aim: *aestimare.*	Hill: *collis.*
To amble: *ambulare.*	Mutton: *mutilus.*
To rescue: *reexecutere.*	Jail: *gabiola*, Greek γαλέα. Ger. *Galeere.*
To search: *circare.*	Clear: *clarus.*
To sound: *sonare.*	Calm: *calmus*, Greek κάυμα καιεῖυ.
To truck: *truccare.*	Fallow: *palleo*, Greek πολιός.

What then remains in a national language?

Thus we all, linguists or not, have come to realise the extremely close relation amongst languages. They are brothers and sisters all with common parents who died thousands of years ago. They are brothers and sisters, only more or less alienated from each other according to the distances they travelled with migrating humanity and according to the circumstances they lived in, circumstances which have their cause and reason in the climate of the lands, in poverty or wealth, in progress or backwardness.

The character of a language cannot be built up by a nation either, for the language is only one of the many characteristic features of a nation, and there are many things in a nation which do not appear in its language, and many things in a language which do not show in the nation which speaks that language.

There are few languages softer, more poetical, more musical than the Spanish, for instance, and, nevertheless, Spain is to-day

a country with little softness, no poetry and much cruelty. And yet it would be unwise to say that there is nothing like a national language.

So long as a language is looked upon only as a means to voice and to word our needs, so long as it only serves, and the speaker of a language is conscious of being served, there is nothing with which to develop a personal character in a language. Any servant may easily be replaced and substituted by another one equally good. Thus the Iberian language has been pushed back into that remote corner which to-day is known as the Basque country, the old Gaelic was replaced by modern idioms, and the endeavour to revive Gaelic may prove a forceful but futile attempt. The Celtic gave way to Latin without visible remonstrance. It is true, in our days a language does not die so easily. Even at the deathbed of a mere dialect we find weeping and mourning philologists busy to administer artistic medicine as a last hope.

An essential point in making a language " national' ' is the national pride, the *Einfühlung*, the conformity of style with the ideal life of a nation. This has nothing to do with purism. A language is not so and so many words linked together by a finite verb or an auxiliary verb. It is the way of styling, the accentuation, in short the sentimental expression, the ability to lay bare one's ideals and ideas by means of the language. Goethe's language abounds in foreign words, but he was the greatest German poet. Whatever critics may say to the contrary, H. St. Chamberlain's *Grundlagen des Neunzehnten Jahrhunderts* is essentially a spasmodic attempt to be German at all costs. H. Heine's French is beautiful, but beautifully constructed and carefully built up, yet it is not felt.

Thus it is not the vocabulary nor the syntax which makes a language national or which prevents a language from becoming national; it is the spirit, the soul, the feeling which bestow the national character upon a language.

In former centuries when nations of a high civilisation lived nearer to nature there was no struggle for the prevalence of a language, no language question at all. Consequently, the nearer a highly civilised nation lives to nature the more national its language. Therefore, the language of the Afrikaner, although still in its very infancy and an offspring of very many other languages, is much more national than English. Afrikaans is a vivid expression of the Afrikaner's soul.

As a language is national only if the people speaking it live near to nature, spreading it can never be a matter of military or economic predominance, nor can the expansion of it be prevented by sheer force. The Italianised Tyrolese will learn to speak Italian, but they will never talk it, because they will never be able to put their soul into it, for the language is the tabernacle of our dreams and our most secret wishes.

In spite of all that has been said, a language, however national it may be, remains second in importance considering national feelings. If this were not so how could Fredric the Great have preferred using the French language instead of the German?

Religion, or rather religious books such as the Bible, with mysticism and romanticism loosely bound together by common nationality or a king or an idol, are often responsible for the preservation of a national language. Luther, translating the Bible, did more for German as a national language than many a poet. This also applies to the Afrikaanse Bybelvertaling, although a conspicuous difference may be noted. For Luther the German language was the means of furthering the knowledge of the Bible. When the Bible was translated into Afrikaans, however, the spreading of good Afrikaans was one of the chief aims the translators had in view. It may be said that the translation of the Bible into Afrikaans is the only means—for the time being at least—of spreading good Afrikaans amongst the Afrikaners, because as long as the old generation of Afrikaners is still alive the venerable custom of *boekevat* and *biduurhou* will not die out. Thus even those living hundreds of miles away from a centre of civilisation will hear good Afrikaans at least once a day.

Studying philology, doing research work in this branch of science, establishing the family tree of a language, creates a purer love for one's own national language and a deeper understanding of it, as well as a less haughty pride in it. To love one's own language has nothing whatsoever in common with politics or imperialism. The love of language is rather a guarantor for the preservation of cultural treasures of bygone days, encouraging man to try to imitate the great men and champions of the language, calling back to his mind the simplicity of his forefathers. To love one's language is a means of seeking the friendly and the peaceful with which to bridge the gaps of political strife. The knowledge of the origin and growth of a language teaches tolerance everywhere.

Our neighbour's mother language is his spiritual eye to see and understand the world around him, it is the voice of his childhood and of his longing. Realising this, everybody should try and put aside all intolerance, because then intolerance will be looked upon as a crime against the life and the soul of our neighbour. Realising this, we feel the desire in us to learn to speak other languages, for each new language opens up wider vistas of our world and creates a new and better personality in us. A new language makes of us new champions for mutual understanding and thus for everlasting peace.

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THE APPLICATION OF WORD-ASSOCIATION TESTS TO CERTAIN GROUPS OF SOUTH AFRICAN SUBJECTS AS AN INDIVIDUAL TEST AND AS A GROUP TEST

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Since 1913, when C. G. Jung, of Zurich, first published his results, word-association tests have been used extensively for measuring the emotional reactions of people. They have been employed for unearthing so-called complexes, for differentiating temperamental types, for corroborating evidence that a particular individual is connected with a certain crime.

The usual procedure of administering the test is as follows: A stimulus word, say " man," is given to the subject, and he is requested to respond with the first word that comes into his mind. The time taken over each response is measured, and the time taken to respond, together with the nature of the response, indicates whether the reaction to the stimulus word is emotionally toned or not.

The present investigation was carried out in two parts with a period of ten years intervening. Round about 1928 the two word-association tests of Jung and of Kent and Rosanoff were tried out on 18 subjects, as individual tests on the lines advocated by Jung.* The associations of each subject were grouped into " inner " and " outer " associations as defined by him. The lists of stimulus words are given by Jung* and by Rosanoff.†

More recently the Kent-Rosanoff test was adapted as a group test by turning it into a multiple choice test, i.e., each stimulus word was followed by a choice of five reaction words, one presumed to be neutral and four emotionally toned. The results of these tests will be discussed separately under the headings: (a) The Individual Tests and (b) The Group Test.

* Studies in Word-Association: C. G. Jung (transl. M. D. Eder), London: Heinemann (1918).

† Manual of Psychiatry: A. J. Rosanoff. N. York: John Wiley & Sons, Inc. (1920).

(a) Individual Tests.

An analysis of the results in the case of the Jung and the Kent-Rosanoff tests yielded the following:—

Subject.		Inner Associations.	Outer Associations.
B.1	Kent-Rosanoff	40	51
	Jung	33	52
	Average	36·5	51·5
B.2	Kent-Rosanoff	52	40
B.3	Kent-Rosanoff	45	48
C.1	Kent-Rosanoff	34	57
	Jung	36	62
	Average	35	59·5
D.1	Kent-Rosanoff	60	29
G.1	Kent-Rosanoff	61	35
H.1	Kent-Rosanoff	46	38
	Jung	63	32
	Average	52·5	35
K.1	Kent-Rosanoff	53	41
	Jung	52	36
	Average	52·5	38·5
L.1	Kent-Rosanoff	54	41
	Jung	55	40
	Average	54·5	40·5
L.2	Kent-Rosanoff	39	59
	Jung	37	62
	Average	38	60·5
M.1	Kent-Rosanoff	36	62
M.2	Kent-Rosanoff	26	66
	Jung	35	59
	Average	30·5	62·5
M.3	Kent-Rosanoff	35	55

(a) INDIVIDUAL TESTS—Continued

Subject.			Inner Associations.		Outer Associations.
M.4	...	Kent-Rosanoff	57	...	36
M.5	...	Kent-Rosanoff	30	...	66
		Jung	36	...	43
		Jung (second)	42	...	42
		Average	33	...	54·5
S.1	...	Kent-Rosanoff	38	...	58
V.1	...	Kent-Rosanoff	37	...	57
		Kent-Rosanoff (second) ...	40	...	49
V.2	...	Jung	43	...	49

From the foregoing it will be observed that in the eight cases tested on both tests plus the two cases in which double associations were obtained on one test, there is a very close correspondence between the number of inner associations and the number of outer associations on alternate forms of the Word Association Test. An actual correlation was not considered worth while, since the numbers were inadequate.

The average disparity between the alternate tests was found to be 4·6 for the inner associations and 6·0 for the outer associations. This shows quite clearly that there is a close relationship between the Jung test and the Kent-Rosanoff test.

Jung recognises two association types:

(a) The " predicate " type, with a preponderance of predicate associations, and an average of 45·7 inner associations and 48·6 outer associations. This type is also known as his " ego-centric " type.

(b) The " non-predicate " type," with fewer predicate and ego-centric associations, and an average of 36·0 inner associations and 58·2 outer associations. This type is also known as his " objective " type.

Dr. Eder* states: " There are certain obvious relationships between the ' objective ' type of Jung and his later ' introversion ' type, and again there are certain resemblances between the ' ego-centric ' type and the ' extraversion ' type of his later view." In his " Psychological Types " he develops the theme of extraversion and introversion further; and lately a number of tests have been standardised in America to measure these traits.

* Studies in Word-Association: C. G. Jung (transl. M. D. Eder).

Glancing back at our results we may classify our subjects into Jung's types as follows:—

"Predicate" Type (Extravision).		"Non-Predicate" Type (Introversion).
H.1 (63 and 32)	Inner and Outer respec.	B.1 (33 and 52)
K.1 (52 and 36)		C.1 (36 and 62)
L.1 (55 and 40)		L.2 (39 and 59) M.2 (35 and 59)
V.2 (43 and 49)		M.5 (36 and 43)

In these nine cases only was the Jung test used, and these results are therefore comparable with Jung's.

The only outside criterion I had for checking this classification was my own intimate acquaintance with the subjects.

With regard to B.1 and C.1, I would have no hesitation in classifying them both as introverts. They are both of a studious disposition and very little inclined to outside activities (e.g., sport). They are both fond of dancing, however.

L.2 presents a different problem. He works in an office, is rather narcissistic, not fond of learning, and is interested in sport though not in an active way. He has recently advanced considerably in business on his own. In spite of his extreme score I would be inclined to classify him as only a moderate introvert.

M.2, a bachelor now in the middle forties, does not strike one as being of an introvertic disposition at first, but on closer acquaintance, and according to his own account, he is definitely of an introvert type.

M.5, despite his moderate score, is a very pronounced introvert, actually verging on the "queer."

Turning now to the extraverts, we have H.1, whom I would have no hesitation in classifying as an extravert. He is in the army and is definitely not given to much thought.

K.1 since deceased, I would, from an intimate knowledge, classify as an extravert. He was a miner and met his death in a motor accident, through no fault of his own; but he had been involved in numberless accidents before; a real dare-devil and adventurous spirit he was.

L.1, a woman teacher, I would have no hesitation in considering as an extravert. In fact, she is a very pronounced extravert, one of those people simply bubbling over with energy and good spirits.

V.2, another female subject, presents rather a problem. She has a very pronounced "will to power," is not well adjusted as the extravert usually is. In fact, I am inclined to think that she is one of those types that are rather unbalanced and habitually swing from a pronounced introvertic attitude to a pronounced extravertic one.

In the following cases the Kent-Rosanoff test only was used, and the results therefore are not, strictly speaking, comparable with Jung's results; but they are given for what they are worth. They are the following:—

B.2 (52 and 40)		B.3 (45 and 48)
D.1 (60 and 29)	G.1 (61 and 35)	M.1 (36 and 62)
M.3 (35 and 55)		M.4 (57 and 36)
S.1 (38 and 58)		V.1 (37 and 57)

About B.2 I have no intimate knowledge.

B.3 I would be inclined to classify as an extravert on the whole, although he has not that facile adjustment to life usually characteristic of the extravert. He is impulsive and of a rather "nervy" temperament.

D.1 and G.1 I would take as typical well-adjusted extraverts.

M.1 is the typical well-adjusted student with brains. He is a definite introvert and has been very successful in his profession.

M.3, in spite of her score, I would be inclined to classify as an extravert.

M.4 is the choleric extravert, unbalanced, impulsive and markedly ego-centric.

S.1, in spite of his occupation, a policeman, I would consider an introvert. Though he is by no means intellectual, he seems to be a seclusive individual. He is very fond of dancing, however.

V.1 is also an introvert. He is a teacher and a very painstaking and hard-working man, a real grinder.

From these results we are therefore justified in concluding that there is a fairly close correspondence between the classification arrived at on Jung's method in regard to the trait extraversion-introversion, and an estimate arrived at in this regard by intimate personal knowledge.

(b) The Group Test.

In order to utilise the Word-Association Test as a group test, and to make the reactions to the stimulus words more comparable. the Kent-Rosanoff list. with a few alterations, was adapted as a multiple choice test. The idea was to turn it into a controlled association test purporting to measure emotionality or emotional maladjustment. The stimulus word was given in large type followed by five reaction words, one supposed to be emotionally neutral, the most frequent association given by Rosanoff in his frequency tables, and four reaction words presumed to be emotionally toned, specially selected with an eye to emotional maladjustment or social maladjustment (delinquency).

This test was administered, in conjunction with a neurotic inventory and certain other tests of emotional and social attitudes, to the following groups of boys:—

(a) 56 telegraph messengers.

(b) 41 orphanage boys.

(c) Boys under the supervision of the Johannesburg Juvenile Affairs Board.

(d) Over 100 juvenile delinquents.

Only the results from the first groups will be discussed here as these groups were used to standardise the test.

The Controlled Association Test follows below. The response followed by an " x " was selected from the frequency tables of Rosanoff, as the neutral response, and the words in italics were the ones given most frequently by the 56 telegraph messengers, on which results the test was standardised. The figures in brackets after each set of responses indicate the number of individuals in the control group, comprising altogether a total of 56, who responded with the responses, adopted ultimately on the empirical basis of the results, as being neutral. The responses other than those in italics were therefore adopted as indicating an emotionally toned reaction to the stimulus word, and the total of the so-called emotionally toned reactions out of a possible 100 gives the " emotionality score " of the subject. This was the score that was correlated with the individual's score on the psychoneurotic inventory.

The Controlled Association Test.

In the following the words in large letters are each followed by a list of five words in small letters. Go through these lists, and cross out in the list the *one* word that in your mind is most closely connected with the word in large letters:

*1. TABLE—*Chair* x, operate, mess, spiritualism, dishes (46).

2. DARK—Fright, *light* x, lonesome, mice, *cellar* (34).

3. MUSIC—*Dance*, hymn, *piano* x, sadness, noise (40).

4. SICKNESS—Poverty, sin, worry, *health* x, *discomfort* (36).

5. MAN—Beast, *manly*, dress, power, *women* x (36).

6. DEEP—*Shallow* x, fall, dread, cave, afraid (37).

7. SOFT—Girl, *hard* x, woman, *silk*, hands (30).

*8. EATING—Poison, work, *drinking* x, poor, nothing (36).

*9. MOUNTAIN—Fear, power, God, *high* x, robbers (44).

*10. HOUSE—Dark, mice, deserted, school, *home* x (33).

11. BLACK—*White* x, ghosts, *cat*, funeral, *death* (43).

*12. BLOSSOM—Flame, *flower* x, paralysed, red, sew (44).

*13. COMFORT—Death, miserable, *ease* x, distress, none (37).
14. HAND—Slimy, followed, sin, *foot* x, *skill* (39).
*15. LAMP—Poor, headache, match, dogs, *light* x (40).
*16. FRUIT—*Apple* x, pinch, desire, watch, none (48).
*17. BATH—Naked, *water* x, choke, alone, danger (38).
18. SMOOTH—Deceitful, razor, *rough* x, *skin*, difficulties (33).
19. COMMAND—*Ten commandments*, dislike, don't, *obey* x, refuse (41).
20. WINDOW—*High*, fall, queer, judge, *light* x (49).
*21. SWEET—*Sugar* x, black, cunning, ugly, unpleasant (52).
22. WHISTLE—*Police*, *noise* x, gang, girl, warning (39).
23. WOMAN—Cat, *teacher*, *man* x, sin, temptation (37).
24. COLD—*Dark*, death, sick, *warm* x, poor (30).
25. SLOW—*Coach*, dead, anxiety, me, *fast* x (39).
*26. WISH—*Desire* x, tired, disappointment, die, broom (39).
*27. RIVER—Dark, *water* x, fear, hypnotize, dead (48).
28. WHITE—Body, *dove*, *black* x, good, innocence (35).
29. BEAUTIFUL—God, hideous, good, *pretty* x, *heaven* (46).
30. RELIGION—*Truth*, crime, longing, sickness, *church* x (48).
31. ROUGH—*Smooth* x, *coarseness*, bold, dirt, poor (35).
32. CITIZEN—*Duty*, *man* x, obey, poor, outlaw (37).
*33. FOOT—Girl, contempt, *hand* x, undress, escape (28).
34. SPIDER—Chills, *crawly*, clammy, *insect* x, female (47).
*35. NEEDLE—Blood, camel, weapon, cross, *pin* x (38).
36. RED—*Colour* x, angler, bull, fright, *hot* (40).
*37. SLEEP—Nightmare, *rest* x, fright, tongue, worry (39).
*38. ANGER—Lover, home, *temper* x, *trick*, laugh (41).
*39. CARPET—Dirt, germs, none. *rug* x, rags (40).
40. GIRL—Health, *figure*, wrong, sin, *boy* x (4)2.
41. HIGH—*Low* x, *dizzy*, fear, fall, power (33).
42. WORKING—School, *hard* x, *ambition*, duty, laziness (36).
43. SOUR—Anger, face, *sweet* x, hate, *nasty* (30).
*44. EARTH—Cemetery, dust, low, *ground* x, body (36).
45. TROUBLE—*Annoy*, father, money, mischief, *sorrow* x (31).
*46. SOLDIER—*Army* x, discipline, police, duty, authority (34).
*47. CABBAGE—Bad, *vegetable* x, decayed, smell, dislike (40).

48. HARD—*Bullet*, face, *soft* x, life, *luck* (41).
49. EAGLE—Cruelty, fierce, *prey*, *bird* x, power (41).
50. STOMACH—*Empty*, steal, want, poor, *food* x (49).
51. LIVING—*Death* x, hard, agony, bare, *make* (33).
*52. DEATH—Water, *life* x, fear, welcome, hopeless (28).
*53. DREAM—Floating, heart, *sleep* x, fear, falling (41).
*54. YELLOW—Coward, flame, ugly, *colour* x, jealousy (29).
55. BREAD—*Crumbs*, earn, hard, hungry, *butter* x (41).
*56. JUSTICE—*Peace* x, unfair, enemy, police, none (36).
*57. BOY—Fear, *girl* x, hit run, disgust (33).
58. LIGHT—Black. away, *dark* x, *sign*, death (41).
*59. HEALTH—Lose, poverty, my, *sickness* x, sin (29).
60. BIBLE—Duty, comfort, home, *obey*, *book* x (42).
*61. MEMORY—*Mind* x, conscience, sorrow, sins, forget (29).
*62. SHEEP—Astray, *lamb* x, black, innocent, stupid (31).
*63. HUNGER—Funeral, poison, *thirst* x, work, shoot (34).
*64. COTTAGE—Alone, burglar, girl, *house* x, afraid (38).
*65. SWIFT—Run, clever, fear, catch, *fast* x (34).
*66. BLUE—*Colour* x, sad, water, lonely, Monday (36).
*67. HUNGRY—Angry, *eat* x, nothing, poverty, often (40).
68. PRIEST—Confession, *God*, *church* x, forgive, sin (36).
*69. OCEAN—Afraid, dark, drown, *water* x, angry (39).
70. HEAD—*Ache*, master, leader, boss, *hair* x (44).
*71. STOVE—*Fire* x, dirt, painful, food, nothing (49).
72. LONG—*Wait*, *short* x, stick, snake, arm (36).
73. PRAY—*Forgive*, sins, *God* x, temptation, good (44).
74. WHISKY—*Curse*, ruin, hit, *drink* x, sorrow (40).
*75. CHILD—Bad, disgrace, nuisance, disobedient, *baby* x (33.)
*76. BITTER—*Sweet* x, family, suspect, life, hope (35).
*77. HAMMER—Annoyance, *nail* x, maul, weapon, strength (38).
*78. THIRSTY—Animal, bar, *water* x, desire, man (37).
*79. CITY—Fun, thieves. life, *town* x, bio-café (29).
*80. FATHER—Temper, drunk, cross, *mother* x, hit (41).
*81. MOTHER—*Father* x, away, nag, punish, cross (41).
*82. DOCTOR—Scream, baby, *medicine* x, death, murder (43).
*83. LOUD—Angry, bawl, *noise* x, shot, fright (39).
84. THIEF—*Arrest*, careful, time, *steal* x, getaway (48).
*85. BROTHER—Fight, hate, lead, trouble, *sister* x (40).
*86. JOY—*Happiness* x, despair, relief, seldom, trouble (49).
*87. HOME—Broken, quarrel, *house* x, sad, nagging (37).

88. HEAVY—*Burden*, heart, weak, *light* x, grief (48).
*89. TOBACCO—Angry, dirty, hiding, disgust, *smoke* x (49).
*90. BABY—*Child* x, dirty, noisy, trouble, nuisance (43).
*91. MOON—Dreaming, *light* x, shadows, struck, afraid (30).
*92. SISTER—Nuisance, tales, *brother* x, hatred, jealous (37).
93. QUIET—*Loneliness*, boring, *still* x, pinching, death (40).
*94. GREEN—Horn, envy, grave, *grass* x, jealousy (41).
95. SALT—*Spill*, disagreeable, preserve, lot, *pepper* x (37).
*96. STREET—*City* x, pals, girls, dark, run (36).
*97. KING—Boss, *queen* x, slave, authority, father (30).
*98. CHEESE—Buried, hang, *butter* x, maggots, never (46).
*99. SCHOOL—Hate, hard, punish, *learn* x, trouble (42).
*100. AFRAID—Anger, fail, guilty, release, *fear* x (39).

Name ....
Age .... years.................. months
Standard passed in school ....
Is your father still living? ....
Is your mother still living?...
Are your parents living together?...................................
If your father or mother is dead, how long ago did it happen?
....
How many brothers have you? ....
How many sisters have you? ....
Are you the eldest child? ....
Are you the youngest child? ....
What are your hobbies? ....
What occupation would you like to follow when grown up?.........

What is your home language? ....
In which suburb do you stay? ....
What is the religion of your parents? ....
Dou you go to Sunday School? ....
Do you belong to the Boy Scouts or Girl Guides? ....
Do you belong to a gang?..
What does your father do? ....
Does your mother also work? ....

In 57 cases out of the 100, the response selected as likely to be neutral was actually established empirically as the only neutral response. These cases are marked with an asterisk.

The frequency of the neutral responses ranged from 28 to 52 in the case of each of the 100 stimulus words for our control group of 56.

Correlations were established with the following tests using this control group of 56 telegraph messengers:—

(a) The Psychoneurotic Inventory as a whole;

(b) The part of the P.I. presumed to measure "Psychopathic Traits";

(c) The part of the P.I. presumed to measure "Neurotic Traits";

(d) The part of the P.I. presumed to measure "Emotional Maladjustments";

(e) The part of the P.I. presumed to measure "Social Maladjustments";

(f) An X.O. test for fears, and

(g) An X.O. test for worries.

The correlations obtained were as follows:—

(a) Controlled Association Test and Psychoneurotic Inventory:

r. = ·609 p.e. ± ·0610.

(b) Controlled Association Test and "Psychopathic Traits":

r. = ·294 p.e. ± ·0868.

(c) Controlled Association Test and "Neurotic Traits":

r. = ·688 p.e. ± ·0486.

(d) Controlled Association Test and "Emotional Maladjustments":

r. = ·825 p.e. ± ·0343.

(e) Controlled Association Test and "Social Maladjustments":

r. = ·647 p.e. ± ·0551.

(f) Controlled Association Test and Combined Fears and Worries:

r. = ·592 p.e. ± ·0610.

As one would expect the correlation between this test and the test for emotional maladjustment is highest, and that between it and the test for psychotic traits lowest. This, therefore, seems to be largely a test for emotional maladjustment, and psychotics, being more introvertic, would presumably react with a greater number of neutral responses (the outer associations of Jung).

The group of orphanage boys were at first tested with the idea of using them as a control group; but on investigation it was found that there was such a high percentage of emotional maladjustment and neurotic tendencies that this group had to be discarded as a normal group. The results obtained from this group are, however, given below for what they are worth:—

(a) Controlled Association and Psychoneurotic Inventory:
r. = ·289.

(b) Controlled Association and Fears:
r. = ·191.

(c) Controlled Association and Worries:
r. = ·222.

For the 56 telegraph messengers the Lower Quartile was found to be 14, i.e., the median of the lower half of the scores, and the Upper Quartile was 34, i.e., the median of the upper half of the scores. Scores of 34 and above were therefore considered as abnormal. The median of all the scores of the telegraph messengers was 19. On this basis 13 scores, or 23 per cent., were considered abnormal for our control group of 56. On the Psychoneurotic Inventory 24·5 per cent. of this group tested abnormal.

For the 41 orphanage boys the Lower Quartile was 22 and the Upper Quartile 40. The median was 29·5. This group was found to show such a high number of scores on the Psychoneurotic Inventory that could be considered above the normal (19 individuals or 46·3 per cent.), that the group had to be discarded as a control The number of individuals who obtained scores of over 34 on the Controlled Association Test in this group was 16, or about 40 per cent.

Another group of 41 boys, under the supervision of the Johannesburg Juvenile Affairs Board, was also tested, to be used as another control group. The median obtained for this group was 20, the Lower Quartile 12, and the Upper Quartile 34, as had been found in the case of the other control group. A score of 34 and over was therefore taken as an abnormal score on this test since it was obtained for both controls. In the case of the Juvenile Affairs Board boys nine individuals, or 22 per cent., tested as abnormal on this test, as against 15·2 on the Psychoneurotic Inventory.

In general this test, therefore, corroborates the evidence obtained with the Psychoneurotic Inventory in regard to the prevalence of emotional maladjustment and neurotic tendencies among the groups of boys tested, the percentages obtained being as follows:—

Group.	Percentage Abnormal on Psychon. Inv.	Percentage Abnormal on Ass. Test.
(a) Telegraph Messengers ...	24·5 ...	23
(b) Orphanage Boys	46·3 ...	40
(c) J.A.B. Boys	15·2 ...	22

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A SOCIAL STUDY OF LAW

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From the dawn of history man, like every other living being, has been engaged in a two-fold process—that of survival and that of self-fulfilment, i.e. the development of all the potentialities contained within him.

In the early stages of his history his main problem would be that of survival, which would comprise the obtaining of food and protection from external enemies.

At no time, however, in his history has man ever stood forth as an isolated individual. This picture of the happy savage is a figment of the imagination.

His very birth brings him into an association of blood with other livings beings, and until his own powers are developed he enjoys the protection provided for him by nature. He is born into a family, and it is this family which is the germ of all the various forms and groups into which society has developed and of the highest form of organisation known to man, the state.

The protection afforded to him by his family would, in the course of time, prove to be inadequate against external enemies, and he has to seek by reasoning processes for other methods of protection. These would naturally suggest themselves in the association with other groups, allied, no doubt, by blood relationship. Thus would arise the larger family, the tribe or the clan, and within this framework man's self-fulfilment would proceed apace; or he would seek actively the protection of some stronger group into whose ambit of development he would fall. He is by now a member of an advanced social organisation; and so on, into the state as we know it to-day.

These represent the broad lines of his social development. It will, however, have occured to us that there is no absolute realisation of the individual man's self-fulfilment possible where he is but one of a number forming a group, the maintenance of whose existence is the condition precedent to his own survival.

There are three concurrent processes that are at work at this stage; man's striving for his own self-fulfilment, the similar striving of the other individual members of his group, and most interesting of all the striving of the group for its own self-fulfilmen. For an organised social group constituted in the way I have indicated has an individuality of its own and possesses its own potentialities of development.

This individual development of the life of the group is exemplified in its most extreme form by the theory of the lives of civilisations. They are born, they develop, outlive their usefulness, they decay and disappear.

At this stage it is clear that the individual member of society is for ever involved in two social conflicts, the necessity for which can never be removed, because they are inalienably associated with that system, which produces the maximum self-fulfilment that man himself is capable of at any particular time.

These conflicts are the conflicts with his private fellow man, which could be put into this form—that every member of society has the right to do whatever he pleases, subject always to the right of the other members of society to do as they please—and the conflicts with the development of the group of such. Both of these agencies the urge to self-fulfilment of his fellow man and that of the group of which he forms a part, limit the scope of his own self-realisation.

The most important consideration for the continued existence of the group is its ability to defend itself against external enemy. For this purpose it is essential that the members of the group shall be organised in the most efficient manner so as to produce the greatest degree of strength for the group.

Any form of internal disturbance is a source of weakness for the group.

The history of mankind teaches us, however, that groups in the forms of organised states of society are constantly disappearing. Man, however, goes on to higher forms of development. It would seem that the urge to the self-fulfilment of the individual is mightier than the forms of social organisations, and it seems that a stage is ultimately reached in the history of every group where the individual within it, with the increased development of his own powers derived from the group, finds it necessary to discard the existing group form and to seek other forms of organisation more capable of developing man's individual personality.

The avoidance of weakness within the group, or the production of the maximum of group strength, can never be achieved at the expense of the sacrifice by the individual of more than a certain minimum of his own individual rights. The strongest state will be such a state as can achieve its own maximum strength by requiring the very minimum sacrifice from its individual members of the energies required for their own self-development.

The function that regulates these various conflicts between man and his fellow man and between man and his group is law.

This law is divided up into private law and public law—private law, which regulates the conflicting rights between man and man; and public law, which regulates the conflicting rights of man and the state; that is, what is known as our criminal law.

The first is designed to give the fullest expression to the rights of the individual, and the second is designed to produce the maximum degree of order, and therefore strength within the state.

It will be clear from the foregoing that law as it exists to-day has not simply leapt into existence. These processes that I have described, the regulation of conflicting rights, has followed man throughout his history. Our law is an historical growth from ancient times. In those respects in which the relations of man to his fellow-man have changed least, i.e. the simplest forms of contract, like purchase and sale, it will be found that the law has similarly undergone only the very slightest change. In fact our law of contract, which is derived from Roman Law, is to a very large extent in the same condition as it was in the Roman law 2,000 years ago.

It is where pronounced changes have taken place within society that similar great changes in the law have ensued, to regulate the new needs produced by the altered conditions.

The social development of mankind, however, has until recently been a very slow progress, and the modifications in the law have in the main required no complex mechanism. Quietly, like the accretions to the land bordering a flowing river through silting, so changes in the law were brought about by gradual adaptations.

Within the last 150 years, however, a new era commenced in the development of mankind. With the new order of ideas associated with the French Revolution and the rise of industry, gigantic changes, within the framework of states, have taken place among the people. Energies that had for centuries been in slumber awakened to activity. Violent disturbances within society caused by conflicts between the different classes led to sudden shiftings of the centre of gravity, and produced vast new problems which could not find their solution in the slower methods that had heretofore been found adequate. It now became necessary for laws to be specifically made of a pronounced social character. This function was performed by the legislature, i.e. in the countries with which we are familiar, by Parliament.

In the result we have a huge body of laws which has arisen within the last 150 years and which is embodied in statutes. This body of law, known as the Written Law, runs parallel with the older Common Law which has come down to us from ancient times.

An era of scientific discovery beginning with the steam engine, industrial machinery, electricity, medicine, surgery, culminating in telegraphy, wireless and aeroplane, has produced extensive and rapid changes in the conditions of living among the masses of society, new needs rapidly arose which had to be satisfied, and claims to an increasing share in the rights and powers of government were made. A new spirit of humanitarianism arose. Slavery was abolished, labour clamoured for

an improvement of its working conditions. Young children had to be protected from economic exploitation. Increase in indus-dustrial activity and in production stimulated the demand of large markets. New types of organisation came into existence. Trusts and monopolies designed to exploit for the benefit of the few the resources of the masses brought into existence the counter weight of trade unions with their protection of labour. All these and others produced stresses and strains within the state which threatened disruption, unless Parliament could produce the necessary laws to cope with the new conditions and with the new social needs.

Social legislation always lags behind social needs and opinion.

" The greater or lesser degree of happiness " as was said by Maine, 70 years ago, " within a state depends upon the rapidity with which the gulf separating the needs of society from its laws is narrowed."

The difficulties of knowing what laws to make in order to cope with these multifarious new needs of society, and the mechanical difficulty of producing these laws speedily, have proved to be great enough to tax the resources of the mightiest intellects. Added to this, the state has become a large business concern with all the difficulties attendant upon the successful management of such a business.

Over and above this all, it is becoming clearer every day that many grave conditions existing in society are caused by factors, economic and otherwise, outside the control of the state. Can it be wondered at that members of society have begun to doubt the efficacy of our law making machinery to save them from disaster?

It is possible that the stage has now been reached that I have previously spoken of when man feels that he has reached the limits of self-fulfilment capable of development within the frame-work of the state as at present organised.

At all events, despair has driven more than one community to seek refuge in a reorganisation of its state. What the outcome will be, what ultimate form the state may assume would be a futile speculation to-day. But it seems safe to say that whatever form it will assume it will, if it is to function at all, have to be one which will enable the process of self-fulfilment of man to be continued, possibly upon a new stage of development, and that states which seek to place a limit to this self-realisation by some theory of complete subjection of the individual to the state, that is to say the sacrifice by the individual, not of the minimum but of the maximum, of his individual personality can only represent temporary phases—the groping in the dark before the light is reached.

As against the disturbing effect produced through the inadequate functioning of the legislature there is the undoubted stabilising effect of the common law—the law which has come

down to us from past ages and from other civilisations long before the rise of our modern states. This common law, rooted as it is in custom, responds to the conservative instincts of man.

There is a natural impulse in all of us to follow the beaten track. This is itself a form of self-protection.

For law to achieve its purpose as a regulator of the activities of members of society, it is essential that the laws be known. In the case of legislation by Parliament this is ensured by proper publication to society, and in the event of society not having the time or the skill to understand the laws as published, the services of experts in the law are available. These are conditions easily satisfied.

In the case of the common law, however, derived as I have already stated from ancient laws and customs and modified in its passage through time by local adaptations, there is no certainty as far as the general public is concerned, and there is also no certainty in so far as its expert advisers are concerned. Clarity can in this case only be obtained by our courts of law.

In spite of this our whole legal system is based upon the presumption that everyone knows the law—an instance of the individual being sacrificed to the group. The hardships that are occasionally experienced in the operation of this principle, however, have induced various states to remedy the defect, and to codify what had hitherto been the unwritten law so as to remove the confusion and obscurity caused by having to delve into the distant past for a particular law.

An associated difficulty in our social system is that courts of law do not sit to advise the people of what the law is, and it will need very little reflection to see that it would be impossible for a court of law to give advice in a matter in which it might have to sit as a tribunal to settle a dispute. This advice, however, is given in a different form, for when a court of law does judicially settle a dispute it thereby pronounces that the rule of law laid down for the decision of the case shall regulate similar transactions in the future. This should serve a very useful purpose in promoting the easy flow of activity between the members of society. But although this should be the result, in practice it is becoming increasingly difficult to achieve.

Apart from the function which it exercises in indicating to the community what the law is, the court sits in the very important capacity of a tribunal that has to settle disputes. With the large increase of activities between the members of society which has arisen within recent times there has similarly developed a larger number of points of contact between the individual member and his fellows, with the result that a larger number of disputes has arisen than ever before. It is a melancholy truth that now, when the services of the courts are most needed for the settlement of these disputes and for a maintenance of free unobstructed and healthy channels of communication between the constituent parts of society, the courts are becoming less

and less active in the discharge of their most vital function, the settlement of disputes. The cause is clear. The pace of human activity to-day cannot brook the delays attendant upon litigation.

The tortuous course of the chancery case Jarndyce versus Jarndyce of Bleak House fame, no longer evokes a smile. It evokes bitter associations in the mind of the litigant. But far and away the worst trouble is the expense of litigation.

It has become such a normal experience for the loser to be ruined by the costs of a piece of litigation in which the amount at issue is quite moderate that few men dare take the risk of gambling with the lives of their wives and children. They prefer ruefully to make a large sacrifice under pressure, but at least to remain with sufficient to carry on their lives. Even the victor on the present scale of things can derive little satisfaction from his victory, because the insolvency of his defeated opponent compels the victor to pay his own costs; a result which in many cases leaves him poorer than if he had foregone his claim entirely.

The insidious results that can flow from this state of affairs are self evident. The man with moderate means is at the complete mercy of the man with wealth, and of the man without any means at all. He can under the threat of litigation be persecuted, oppressed, blackmailed and driven to utter despair. It is one of our claims that our courts meet out justice equally to all and know no distinction between poor and rich. This is true in theory, just as it is true, according to Anatole France, that it is equally the right of the poor and the rich to sleep through the winter nights on the embankment. Man is more immediately interested in the practice than the theory.

An examination of the recent activities of our civil law courts will reveal that on the whole the only cases which come before them are those in which its services are indispensable, such as cases for divorce, estate matters, and applications for judgments in which it is necessary to obtain redress against an opponent by way of execution by the state against his assets.

The result of this is to produce an undercurrent of discontent with the social system, possibly not strong enough in itself under normal conditions to cause disruption, but capable in favourable circumstances conjoined with other grievances of producing an explosion.

I come now to the court of justice exercising its criminal jurisdiction. As I have already explained, it is necessary for the healthy functioning of a state that there shall be internal order. The mark of a well governed state, it has been wisely stated, is that the element of force is never brought to the surface. The force, however, is there, and it is brought into activity in its controlled form by the courts of law sitting as a tribunal to punish offenders.

Although in one respect the court functions here to protect society from the individual offender, the principle in our law

upon which every man is presumed to be innocent is an example of the opposite principle by which the freedom of the individual as against society is safeguarded.

Moreover, the claims of the individual have received further expression in the application of humanitarian principles to our law of punishment. It is a mark of our enlightened times that the rigour of the punishment inflicted upon criminal offenders not so very long ago has been considerably abated. With the advance of knowledge and the education of the masses there has developed a social conscience which is inclined to see in the court sitting as an avenging deity, a mere piece of barbarism. An illustrative example of this process is found in the palpable evasions to which juries used to resort as recently as 100 years ago. In those days, in England, the punishment for theft in a dwelling house of an article of value £2 was death. There is something satisfying about the subtle way in which juries succeeded in bringing the value of the stolen article below the £2 mark. In one case a £10 Bank of England note was found to be worth only 39s.

Medical and psychological opinion have had in more recent times a great influence in the improvement of our laws of punishment. So much so that there is at present a large school of thought outside the courts of law which claims that the criminal should be treated as a psychopathic subject, and should not be punished as if he were responsible for his actions. The view which prevails in the courts of law is that every man must be held responsible for his actions, unless he comes within certain defined exceptions, children, for instance, and lunatics—and the principle that is applied is that by the punishment of the individual offender other potential offenders will be deterred. As a subsidiary ground punishment is also directed at preventing through the experience of punishment the recurrence of an offence by the same offender.

I do not intend to discuss the merits of this controversy beyond saying this, that society has not yet advanced to the stage when Parliament would pass legislation providing for the treatment of offenders on the psychopathic basis, and the courts have to be careful that by not inflicting the punishment which society has decreed, in many cases in the express terms of a parliamentary statute, those who have immediately suffered by the offender's action in contravening the laws are not encouraged to take the punishment of the offender into their own hands, with the grave danger in more serious cases of the terrible lynchings which now and again manifest themselves in certain countries.

The natural leaning of judges is on the whole to leniency in the interests of the individual, but they cannot shirk their responsibility to society as a whole. It should not be forgotten, however, that the sentences imposed are subject to important checks. The Government always has the right to mitigate a judicial punishment, where the social conscience becomes out-

raged by its undue severity or where other circumstances demand intervention.

The remedy for such defects as exist in our present system seems to lie in the improvement of the social conditions under which people are required to live and in the education of the members of society. For with all our enlightment there are traces of the savage in most of us.

The real reforming agency under modern conditions is not the court of law at all, but the prison. Here, too, a great step forward has been taken from the " durance vile " days when there existed no theories of punishment beyond that of ridding society of every offender.

It is the professed object of every enlightened state to secure such conditions in their prisons, and to apply such principles as may bring about a change of social outlook in the individual.

Unfortunately the rate of improvement is not as rapid as many of us desire. There is room for great improvement, but impatience undergoes immediate restraint when we compare the conditions that exist to-day in a country like South Africa with those at any other time in any place in the history of civilisation.

To deal lastly with the judiciary. The most perfectly conceived system of courts without an efficient judiciary would be but an empty shell—and mere learning is not the test of judicial efficiency. There can be little dispute as to the immeasurable advantage enjoyed by those states which appoint their judges from the practising lawyers over those which recruit them from the civil service.

The great reputation of our judiciary for incorruptibility, impartiality, fearlessness, subservience to no authority but its own conscience, could never have been obtained except under the methods of judicial appointment prevailing in all British countries.

The security of the position of a British judge lies in this, that he cannot be removed except by resolution of both Houses of Parliament, in other words by vote of the whole nation.

The practising advocate is not a free agent. He belongs to a profession with great traditions, and a high standard of conduct is required from him. A man who has successfully passed through the experience of a practising advocate in a British court of law will invariably prove to be imbued with those qualities which are required in a good judge, and above all, in that quality which has made of our judiciary a greater thing than an expositor of law, or an official arbitrator—the champion of man's freedom against the encroachments of executive authorities.

In the British judicary of to-day is to be seen the most substantial advance made by man in his social struggle. Let nothing imperil its safety or impair its efficiency.

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